NEW CENTURY PHYSIOLOGIES

HIGH SCHOOL ·PHYSIOLOGY·

NEW CENTURY SERIES

OF

ANATOMY PHYSIOLOGY AND HYGIENE

BY

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INDORSEMENT

We, the undersigned, have carefully examined the school text-book entitled

ANATOMY PHYSIOLOGY AND HYGIENE FOR HIGH SCHOOLS

by Dr. Henry F. Hewes, with reference to the following points:

1. Fullness and accuracy of subject matter relating to the nature and effects of alcoholic drinks and other narcotics upon the human system.

2. Amount of matter on general hygiene.

3. Presentation of matter with regard to its adaptability to the class of students for which it is designed.

We are satisfied that on all of these points, as well as in the regular anatomy and physiology, the treatment is as complete as is required for a book of this grade, and fully in harmony with the results of the latest investigations. We therefore heartily indorse the book for High School grades or pupils.

Text-book Committee:

MRS. MARY H. HUNT,
World's and National Superintendent of Scientific Temperance Instruction for the Woman's Christian Temperance Union.
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W. P. I

PREFACE

THE great and universal factor in progress is education. Correct action is dependent upon correct thinking. The more familiar a man is with the laws of nature the more he will obey them and work in harmony with them, to the benefit of himself and his fellows.

In no branch of education is this connection between knowledge and conduct or welfare more direct than in that which deals with the study of our own bodies, and of the laws and practices which must be observed in order to maintain a condition of health and activity in these bodies — that is, the study of physiology and hygiene.

For upon the observation of these rules of hygiene depends the preservation of health, a first essential for usefulness as well as enjoyment in life. He can best and most intelligently observe these laws who is familiar with and understands the facts from which they are deduced, the phenomena of physiology.

This study should therefore be a part of the education of each and all of us. It should be taken up in youth, for it is during this period that the organs and tissues of the body, the frame, the heart, the brain, are growing and taking on the character which they keep throughout life, and that the practices and habits which are the most deep-seated and fundamental are forming. The health and character then acquired often prove the bed rock of the whole physical, mental, and moral development. The errors committed then are often irreparable, and it is the province of our educational systems to insure that at least these errors shall not be committed through ignorance.

In preparing a text-book for this purpose of general education in the schools, the point to be kept most in mind is the unity of the subject.

The physiology is the description of how our bodies are nourished and how they work. The hygiene is the code of instructions which directs how to keep this body nourished and in working order, and is deduced directly from the study of the physiology.

It is a criticism of many of the school physiologies that with them the subject is presented as a series of lectures upon several organs and their special functions, rather than, as it should be, as a single treatise upon one organ, the body, and one function, life.

Whatever may be the special functions of special organs, the primary function in which all coöperate is the maintenance of life and activity in the body by the provision for nourishment of its tissues, energy for its work, and disposal of its waste.

So it is that physiology is primarily the study of the course of the food elements through the body from the ingestion by the mouth, throughout the distribution, utilization, and combustion in the various organs and tissues, to the elimination from the body — that is, the study of physiological chemistry.

In this conception particular attention has here been given to this fundamental department of physiological knowledge.

In addition to the strictly fundamental matter upon anatomy, physiology, and hygiene, the book contains special chapters upon the cause and prevention of infectious diseases. The study of bacteria and of the diseases which they cause has brought to light much knowledge which, if distributed generally, would guide the public in controlling and preventing the spread of the harmful conditions consequent upon bacterial action. It seems wise, therefore, to include this knowledge in a general text-book upon hygiene.

A special feature of the book is the experimental work, which, while avoiding dissections, is designed to enable the teacher to dispense with cram methods by furnishing abundant opportunity for individual investigation and observation.

Throughout the work the author has endeavored to include the results of modern investigation and to introduce the experimental spirit which is the active force of all learning. He has endeavored also to make the connection between the rules of hygiene and the facts of physiology, from which these rules are deduced, as clear as possible.

In these chapters upon hygiene a considerable space has been devoted to the consideration of the status of the habit of alcohol drinking from a hygienic standpoint. In view of the menace to the health and happiness of the human race which lies in this habit, a thorough statement of the truth in this regard is necessary in a schoolbook of this kind.

The author is indebted to Messrs. William Wood & Co. for permission to use in the preparation of his illustrations several plates belonging to them.

HENRY F. HEWES, M.D.

HARVARD UNIVERSITY.

CONTENTS

INTRODUCTION

THE STUDY OF THE HUMAN BODY

THERE are no objects upon the earth which arouse in us more wonder and interest than the great machines which have been fashioned by man. The locomotive running at tremendous speed over miles of country, the mill machines which take in the crude cotton and turn it out as cloth, the mowing machine, the clock, all seem to us marvels of ingenuity and power. The working of the complicated systems of pistons, levers, wheels, and cogs fills us with curiosity and amazement.

Wonderful as these productions are, however, the most ingenious and perfect among them is, in intricacy of design or efficiency for work, but a plaything in comparison with the machines which nature has fashioned for us all—our own bodies.

You are all familiar with the performances of this machine of nature's making, the human body. You know that it can transform bread and water and vegetables into flesh and bone and hair. You have seen it run, bound over brooks and walls, swim, climb, by various movements of its parts. You have felt the heat that it is constantly forming. Through the eyes it collects the images of the surrounding objects, through the ears the sounds of wind and wave, the humming of the insects, the singing of the birds.

Doubtless all of you have wondered much about these

workings of your own bodies, and about the secret processes which go on within them: how the skin and bones are formed from the food; how the constant breathing and the beating of the heart are kept up night and day through long years; why the breath makes a cloud of vapor upon a cold night; why we sleep; how the boy grows to the man; what the property is within us which makes us live and change instead of remaining lifeless and apparently changeless for all time, like the water and the rocks. These and many more questions in regard to the workings of your bodies must have frequently entered your minds.

And it is very important that you should be able to answer them; for it is through the possession of a knowledge of the body and its processes that we are able to keep these bodies in health and usefulness. Just as the engineer must understand the mechanism of his engine, so every man should understand the parts and workings of his body in order to run it properly.

It is for the unfolding of these secrets of the body mechanism that we take up the study of anatomy and physiology, the sciences of the structure and functions of this body.

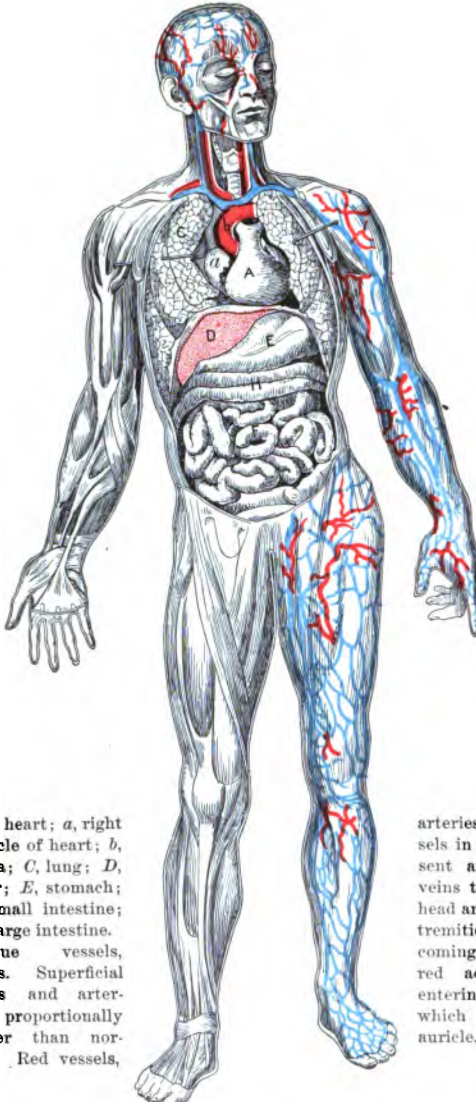
As we have said, the body is a machine. It performs a certain definite work and has a definite manner of action. It is kept going by energy which is obtained from the burning of substances within it, just as the engine is kept running by the energy derived from the burning of coal in its furnace; and, as in the engine, this burning causes heat. To keep up this constant burning it has to have a constant supply of fuel put into it, just as the engine has its coal shoveled in. The material which is turned into fuel, the food, is distributed throughout its parts by vessels, and the energy derived from the food is distributed by nerves, just as the steam of the engine is carried about by pipes, or the energy of the electrical machine by wires.

Now, in order to study a machine we first examine the general form and structure of the apparatus as a whole, ascertain the names and relations of the various parts, and get some general idea of their functions. Then we take the machine apart and investigate the structure and workings of each piece, so that we may be thoroughly familiar with each step in the performance of the work of the apparatus which we are to direct.

So in the study of the body we must first obtain an idea of its general form and structure. We must record its parts, their positions, their general relations to one another, and their functions. We must investigate the general character of the work which the body has to perform, and the fundamental process by which its work is accomplished. We must trace the food which enters by the mouth through its processes of digestion, absorption, circulation, and assimilation, until it becomes built up into flesh, bone, or blood. We must study the burning of the body fuel in its cell furnaces, with its production of heat and energy, and how this energy gets to the heart and muscles and brain, and enables them to work. And finally we must see how the waste products of the burning and wear of the tissues, the ashes, are disposed of. Then we must study separately the various organs, and the special functions which they perform in forwarding the work of the whole organism.

Heard are the voices,
Heard are the sages,
The worlds and the ages;
Choose well: your choice is
Brief and yet endless.

GOETHE.



A, **heart**; *a*, right **auricle** of heart; *b*, **aorta**; *C*, lung; *D*, **liver**; *E*, stomach; ***F***, **small** intestine; ***H***, **large** intestine.

Blue vessels, **veins.** Superficial **veins** and arteries proportionally **larger** than normal. Red vessels, arteries. **Large vessels in neck represent arteries and veins to and from head and upper extremities; arteries coming from dark-red aorta; veins entering large vein which enters right auricle.**

Full figure, with viscera exposed.

Not in the World of Light alone,
Where God has built his blazing throne,
Nor yet alone on earth below,
With belted seas that come and go,
And endless isles of sunlit green,
Is all thy Maker's glory seen—
Look in upon thy wondrous frame:
Eternal Wisdom still the same!

HOLMES.

CHAPTER I

A GENERAL SURVEY OF THE STRUCTURE AND COMPOSITION OF THE BODY

I. THE GENERAL STRUCTURE OF THE BODY—ANATOMY

IF we look at the human body we see that it is made up of a central portion, or *trunk*, to which are attached the *head* and *limbs*. If the body be marked off into right and left halves by a line through the center from top to toe, it will be found that the two halves externally look practically alike. Each part on one side has its counterpart upon the other side.

Over the whole surface of the body is the *skin*.

Beneath the skin we can feel the *muscles*, and beneath these the *bones*.

The bones are built up together to form the frame, or *skeleton*, of the body. Upon this frame the muscles are attached in such a way that they can move one part of the

frame upon another. Within the cavities made by the bony and the muscular frame lie the organs of respiration, the lungs; the organs of digestion, the stomach and intestines, the liver; the organ of circulation, the heart; the central nervous system, the brain and spinal cord; the organs of excretion, the kidneys and bladder. Throughout the bony frame, the muscles, the skin, and the organs within, run blood vessels, which carry the blood, with its food and oxygen, to all these parts and bear away the waste. To and from all these parts run nerves, through which the functions and actions of the parts are controlled.

The study of the structure of the body is called *anatomy* (Greek *ana*, "through," and *temno*, "I cut," referring to the study of anatomy by dissection).

II. STRUCTURAL MATERIALS OF THE BODY—TISSUES AND CELLS—GROWTH

Tissues. These parts which compose the body—the bones of the skeleton, the muscles, the skin, the various organs, as the stomach, the lungs, the eyeballs, the brain—are in their turn composed of different kinds of material, known as tissues (Latin *texere*, "to weave"), built up together in their structure. There is muscle tissue (meat is made of this kind of tissue) and bone tissue and brain tissue, etc. These differ in appearance just as the woolen cloth of a suit and the cotton cloth of the lining differ, and they are built up together just like these cloths in a suit. (See derivation of "tissue.") Thus, in the stomach we have the walls made of several kinds of tissue, bound together very much as are the cloth and lining and stiffening material of a suit of clothes.

In this method of formation the body may be likened to a house. The skeleton of the body corresponds to the frame of the house, the skin and the muscles to the walls, the

mouth to the doorway, the windpipe and gullet to halls and stairways leading to the rooms within, the eyes to the windows. Just as these parts of the house are built up of combinations of different materials, so are the parts of the body built up of similar combinations of materials known as tissues. Thus, the frame of the house is composed of wood and iron built up together; the skeleton of the body is composed of bony tissue; connective tissue, cartilage tissue, built up together. The walls of the house are composed of brick and mortar; the walls of the body of epithelial tissue, connective tissue, fat tissue, and muscle tissue, built up together just as are the brick and mortar.

Cells. The tissues in their turn are made up of minute structures called *cells*, arranged together in different ways. Just as the brick and mortar are each really a large number of fine particles of clay or lime stuck together, just as the cloth is many fine threads woven together, so the connective tissue and the bony tissue are made up primarily of a large number of small bodies placed together. Here, however, the resemblance between the formation of the materials used in building the body and those used in building a house ends. For the particles which make up the brick or iron are dead bodies which never change, while the cells of tissues are live bodies which grow and change their shape and the shape of the tissue which they form. Every tissue may be said to begin as one cell. This cell grows and divides into two cells lying side by side, and these new cells into more, and so on until we have a great mass of cells built up together.

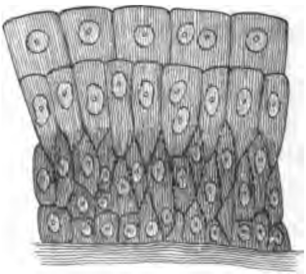
Cell processes and intercellular substance.

In thus growing the cells may develop long *processes*, or sprouts, and produce also *intercellular substance*,

Varieties of cells.

a jellylike material which is deposited about and between them. The masses of cells, with their processes and the intercellular substance, growing together in this way, form a tissue.

Varieties of tissues. These cells may take different shapes and arrange themselves together in different ways. This variation in the character and arrangement of the cells gives rise to different kinds of tissues. Thus, the cells may be cubical or polygonal in shape and lie side by side like stones in a wall, with

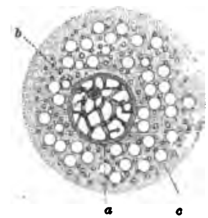


Epithelial tissue.

Connective tissue.

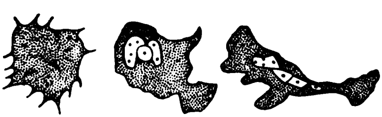
very little substance between. Such a formation is called an *epithelial tissue.* Or the cells may be spindle-shaped or triangular, with long processes crossing each other and twisting together, so that the tissue looks like a skein of silk or a net. Such a tissue is called a *connective tissue.*

The cells of a special tissue form only this kind of tissue. So that when we have a structure, as a bone or the skin, made up of several kinds of tissue, we have had several kinds of cells all growing together and producing their own tissue. These tissues thus collected form the part or organ.



A cell, highly magnified.
a, nucleus; *b*. nucleolus; *c*, cell body of protoplasm with granules and vacuoles.

The cell. The cell is therefore the unit of structure. The single cell is a minute structure consisting of a mass of soft granular substance, containing a dense body, the *nucleus*, in its center. A fully formed cell consists of three parts: 1. The *cell body*. 2. The dense *nucleus* (Latin, "a kernel"), imbedded in the cell body. 3. A very dense body looking like a dot in the nucleus, the *nucleolus* (Latin, "a little kernel"). Seen under the microscope, alive and floating singly in the blood, a blood cell looks something like a jellyfish. The cells of different tissues vary in shape and size and in the plan of their arrangement. Some are spherical, some flat and rectangular; some are spindle-shaped and have processes many times longer than themselves, which help to make up the tissue of which they are the cells.



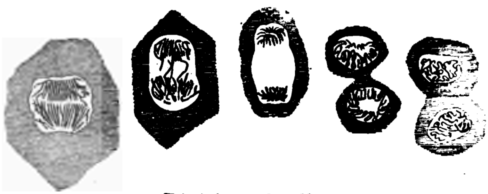
Amœboid cell, showing changes in shape due to its motion.

Properties of cells. The cell as it exists in the body is alive. It takes up nourishment, builds up substances within itself, reproduces its kind. Some cells have the power of motion, known as *amœboid motion* (Greek *ameibo*, "I change") (see Glossary). By this motion, which enables the cell to change its shape and to throw out processes, it can become long and

thin, so as to slip through fine openings, or can surround a particle of substance with which it comes in contact.

In the cells all the vital processes of the body occur. They are the furnaces in which the combustion which produces the body energy takes place. In them the growth of the tissues goes on.

Growth. Growth of the body parts and tissues takes place primarily through the cells. At the start, as described, the cells divide, forming more cells; they develop processes and fibers, and form intercellular substance, in this way building up tissues, which, forming together, make the parts and the organs. Throughout childhood and youth this formation of new cells and new tissue is very active. Tissue is formed much more rapidly than it is used up, and thus the body and its parts grow larger.



Division of cells.

With manhood the cells cease to grow and produce so actively. They simply produce new tissue about as fast as it is used up in the work of the body, and so, as the important parts, the bones and heart and lungs, grow no greater, the man remains of the same height.

Cell activity. The health of the body depends upon the perfect action of its many organs; and the action of these organs depends upon the healthy activity of the cells which compose their tissues. Nature does all it can to provide the best conditions for the activity of these cells. Thus, the cells are most active in a temperature of 98° to 100° F. or thereabouts; and so we find that the body temperature is kept constantly between these limits. When a part of the

body is exposed to very cold temperature, the cells of the part may become so cold that they die. In this case the processes of life, the work and repair and growth, can no longer go on in the part, and it wastes away. Some travelers have lost their fingers or toes, or even their feet, in this way.

There are other influences which may injure these cells besides cold. Thus, irritation of the cells by acids or alcohol or other irritant substances may do so. Contact of the cells with poisonous substances, as tobacco, cocaine, opium, etc., will do the same thing. If we pour strong alcohol upon a growing plant or upon the mesentery of a frog we can see the tissues shrivel up and the cells lose their activity under its influence.

III. CHEMICAL COMPOSITION OF THE BODY

Protoplasm. All the tissues and cells of the body are composed of one fundamental material, known as protoplasm (Greek *protos*, "first," and *plasso*, "I form"—original substance). Many substances—lime, iron, etc.—enter into the composition of the tissues, but all, when present, are combined in this original ground substance, which is present in every cell or substance in which life exists.

Protoplasm is a compound chemical substance; that is, it is composed of several simpler chemical substances. This we know because upon breaking it up we obtain from it several separate substances, which of course must be its constituents.

FUNDAMENTAL COMPOSITION OF MATTER—ELEMENTS AND COMPOUNDS

Most substances which exist as definite materials are composed of two or more separate substances united in chemical combination; that is, they are chemical compounds. If we break them up we obtain these several separate substances from them. Thus, if we break up wood by burning it under proper conditions we obtain the simple substances carbon, hydrogen, oxygen, etc., from it. If we break up water we obtain hydrogen and oxygen.

The substances which we obtain by breaking up compound materials differ from these materials in one important respect. They are simple substances. They cannot be further broken up. No matter what we do to the carbon obtained from the wood, we cannot divide it into any substances not carbon. These simple substances which cannot be further divided are called *elements.*

All substances which exist are either single elements or combinations of several of them (hence the name "element," from *elementum,* "first or constituent principle of anything"). The names of several of the common elements are carbon, oxygen, hydrogen, nitrogen, iron, sulphur, phosphorus, chlorine.

These elements may exist as separate substances. Thus, charcoal is the element carbon. Oxygen exists as a gas in the air.

But most of the carbon and oxygen and of the other elements exists in a state of combination with each other in the many compound substances.

The small particles of these original constituents or elements which exist in these combinations, as the finest particles of carbon in wood or oxygen in water, are called *atoms* (Greek *a,* privative, and *temno,* "I cut"—not to be cut or divided any further).

Organic and inorganic compounds. Compound chemical substances are divided into two classes, the organic and inorganic.

Organic substances are principally those formed as a result of the action of living cells, that is, substances found in or coming from the bodies of plants or animals, living or dead.[1]

[1] These descriptions of organic and inorganic substances are given to convey to the reader an idea of the nature of the substances which belong to each class. They are not intended for definitions.

The only definition which accomplishes an approximately absolute distinction be-

They may, however, be built up independently of the action of living cells. Most of them burn. Such are muscle, brain, bone, wood, and coal.

Inorganic substances are for the most part those which make up the mineral world, the rocks, and water, salt, etc. Many of these inorganic substances are found in the living body, as water and salt. They may be combined by the action of living cells into organic substances, as the lime is built up with other substances to form the organic substance bone.

Protoplasm is an organic compound. It contains three important organic substances, *proteid*, *carbohydrate*, and *fat*, besides water and many mineral substances.

These proteids, carbohydrates, and fats form the principal organic compounds of the body.

The chief inorganic compounds are water, salt (chloride of sodium), lime (calcium carbonate), and phosphates.

The chief elements found in the body, all in combination, are oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, chlorine, sodium, potassium, calcium, magnesium, iron.

DEMONSTRATIONS AND EXPERIMENTS

A certain number of experiments are given with each chapter to enable the pupil to determine for himself some of the facts which he finds stated in the text.

The limited facilities of most secondary schools restrict the application of the experimental method of the study of physiology.

The experiments given here are for the most part so simple that each pupil may apply them. More difficult experiments may be demonstrated by the instructor. A useful collection of experiments will be found in the "Outline of Requirements in Anatomy, Physiology, and Hygiene for

tween organic and inorganic substances is the chemical one, which classes all compounds containing carbon as organic; all those without carbon, inorganic.

This definition is not a useful one for purposes of physiology, however, and it is best to consider the substances after the above descriptions.

Entrance to Harvard College," also in Peabody's "Laboratory Exercises in Anatomy and Physiology."

1. **The use of the microscope.** The study of cells and tissues can be made only by means of a microscope. A compound microscope such as is needed for observations of this kind consists of two lenses set in a movable tube. The lower lens or objective does the main part of the magnifying. The upper lens is called the eyepiece. The movable tube is set in a stand in such a manner that the distance of the lower lens from the object to be studied can be varied.

Below the stand is a mirror arranged to throw light directly upon the object through an aperture in the *stage* upon which the object rests.

The object to be examined is placed upon the stage over the aperture and below the lens. The light is thrown upon it by the mirror. The tube is then moved up or down until the object can be seen clearly through it. This finding of the clear image of the object is called *focusing*. It is accomplished by keeping one eye at the eyepiece and pushing the tube to and from the object until this is clearly defined.

A lens is said to magnify so many diameters according to the number of times it enlarges the diameter of the object viewed. Thus, a microscope fitted with lenses which make a cell appear two hundred times its natural diameter is said to magnify two hundred diameters.

In studying cells a microscope magnifying at least two hundred diameters should be used.

2. **Cells.** To observe the appearance of a cell, scrape the surface of the tongue, and place the mixture of saliva and tissue substance thus obtained upon a glass slide, and cover with a thin glass cover slip. Several of the flattened superficial cells of the mucous membrane of the mouth cavity will be found upon moving this slide about under the microscope.

3. Scrape the skin, and place the "dust" thus collected in a drop of water upon a slide, and observe as above. The flattened cells which are constantly wearing away upon the surface of the skin will be seen.

4. Examine a drop of blood taken upon a cover slip and spread upon a slide. The white corpuscles here are cells. Note their amœboid motion.

QUESTIONS

I. What is anatomy? Describe the general plan of structure of the body. Name some of its structural parts. What is the trunk? What

parts should we come upon in our course if we removed the skin and one by one the parts beneath it until we reached the center of the body trunk? What name is given to the substance of which organs or parts of the body are made? What does muscle tissue look like? What does bone tissue look like externally?

II. How does each tissue begin? What besides cells goes to make up a tissue? What is a cell? How do cells differ in appearance? What do cells do in the body? How do tissues and parts grow? What is the difference between growth in boyhood and manhood?

III. What is the fundamental substance of living tissue? What is the difference between a chemical element and a compound? Define an element. Name one. Define a compound substance. What are organic compounds? Name some inorganic compounds. What are some of the properties of organic substances? Name three important organic compounds found in the body. Have you any protoplasm in your body? Where?

CHAPTER II

PROCESSES OF LIFE IN THE BODY—OXIDATION—METABOLISM—PHYSIOLOGY AND HYGIENE

WE have now outlined the general structure of the machine which we call the body. We have seen that it is built of many separate parts, all of which are composed of different materials, known as tissues; that these tissues are formed by the growth of many small bodies, known as cells, and that these cells, and therefore the tissues and the parts, are composed fundamentally of a substance known as protoplasm.

We must now endeavor to form some idea of how the machine works; from what source and by what processes it obtains the energy through the agency of which its activity is maintained; in other words, how the property of life which is present in the finest particles of the body substance, the cells and tissue elements, is kept up continually.

Life and death. Life may be likened to a fire which burns on unceasingly in every particle of the body. In the cells of each tissue and part, the brain, the heart, the blood, the skin, it burns on as long as there is fuel and oxygen for the burning. While it burns, the body is alive; it takes nourishment, grows and repairs, and does what work it is called upon to do to keep the life flame within it. (See note, p. 28.) When the fire goes out in any part, that part

is dead, and can no longer grow or work.[1] When it goes out throughout the body, the body dies. Its movements cease, its wheels run down, its heat fails. The blood no longer flows through its parts. The cells and tissues dry up and decay, and their elements return to the earth, to be again built up into plants and other animals.

The maintenance of life — Building material and energy. Now, in order that this life fire may continue burning in the cells and tissues throughout the body, the body must have two things. These are, first, material for the maintenance and repair of its tissues; and, second, energy for its action.

I. The burning of the life fire, with the processes and activities necessary for its maintenance, is continually wearing and wasting the substances of the tissues. The protoplasm of which the cells are built is constantly being used up. To offset this constant wasting of the tissues, the body has to supply them with new material as fast as their own is used up. This material it gets in the *food*, which it takes in and distributes, and builds up into new tissue. Thus the integrity of the body is maintained.

II. All these processes of keeping the tissues nourished, the procuring of food, eating it, distributing it into the tissues by the circulation, building it up to tissue by the cells, —in fact, all the processes necessary for the maintenance of life,— entail a certain amount of work by the body; for when a cell is building up a new substance it is doing work just as is a man in building up a wall.

To do this work the body has to use the second thing which it must have for the maintenance of life, i.e., *energy*.

Energy. It is difficult to give a comprehensive definition of energy which will be easily intelligible; for energy

[1] Thus, when a finger or a toe is so thoroughly frozen that all the cells which make up its tissues lose their power to work, to build up and to burn the food supplies, the part dies. It becomes cold and shrivels up.

appears in several different forms, which are totally unlike in their outward character. In connection with work, energy means power, strength in action. When you lift a stone a certain amount of power or strength is necessary. So in each movement of the arms or jaws, each beat of the heart, the body has to use some power or energy.

Source of energy. The body gets its building material from the food; where does it get its energy? The answer to the question is that the body gets energy indirectly from the same source from which it gets its building material, but *directly from its own tissues.*[1]

There is a great deal of this energy everywhere about us. It exists in the sunshine, in the wind, in the trees and plants, in coal, and in our own tissues. If we want to use it we simply have to find some way to get it out of these things and to appropriate it for ourselves. We use the energy of the wind for sailing or for turning a mill. If we want to get the use of the energy which is stored up in coal we burn the coal. By this process the stored-up energy is set free and can be used to make steam for running an engine. If the body needs, for work of any kind, the energy which is stored up in its tissues, it gets it by burning these tissue stores. When these tissues are burned their energy is set free. Some of it goes to form heat, some of it goes to perform work, and thus the movements of the body are performed.

The power which the body needs for work at a given time is therefore already in the body tissues, and needs only to be liberated by the burning of these tissues to be useful for work.

The storage of energy in the body. The next point to establish is how this energy becomes thus stored up in the tis-

[1] Some of the food may be burned in the body without previous incorporation into the tissues, but this is not true of the larger part. Most of the body energy comes from the burning of tissue into which the food has been incorporated.

sues, and how its supply there is kept up. As we have already hinted, it gets to the tissues in the food.

The energy comes primarily from the sunshine. It is derived from this through a complex process of nature carried on by the plants. Man uses these plants, or the tissues of animals which have fed upon them, for food, and thus takes into his body the energy which they have acquired from the sunshine.[1]

The elements of which our food consists, the carbon, oxygen, nitrogen, hydrogen, etc., exist in a free state or in simple compounds everywhere about us in the soil and air. The plant takes them and unites them into compounds, such as starch, sugar, proteids, and fats, and out of these compounds builds up its own structures, its stalks and stems, its grains of wheat or rice, or apples or potatoes. To do this building requires energy, which the plant borrows from the sunshine in which it is bathed. This energy remains stored up in the compounds as long as they exist. When these compounds are broken up the energy is liberated.

The wheat or rice grains thus consist of many of these atoms or of these simpler compounds of carbon, nitrogen, oxygen, etc., held together in a more complex structure known as wheat, and the wheat contains not only the carbon and nitrogen compounds, but also the energy which has been used to build them up together, and is now holding them together as proteid and starch in wheat. So that if you eat a wheat grain you take into your own body a certain amount of energy which the plant borrowed from the sun in making the wheat. Thus, when we eat vegetables and grains and build them up into flesh and bone, we are taking great stores of energy into our own tissues. And

[1] This transfer of the radiant energy of the sun through plants and animals until it is used to heat the body, or for work, as walking or thinking, is one marked illustration of the law of the correlation of forces (or energy).

the tissues become like storage batteries of electricity, charged with energy which they can liberate.

The liberation and use of energy in the body. To use this energy the body, as we have said, burns the tissues. Each tissue cell is in reality a minute furnace in which the starches, sugars, and fats are *oxidized* (see definition of "oxidation" below), or burned.[1] The process is the same as that which takes place when wood and coal are burned in the furnaces of an engine. Heat is evolved in both cases. In the body oxidation goes on slowly, and as a result the body is kept only comfortably warm. In the furnace this process goes on rapidly, and much more heat, as well as flame, is given off.

This burning, or combustion (Latin *comburo*, "I burn"), results in the breaking down of these substances which have been taken in and stored up there, in the eating and assimilating of the wheat or potatoes. The small blocks of carbon, oxygen, hydrogen, etc., which make up the compounds all fall apart again. The energy which was used in holding these small blocks together, as the large wheat block, is set free and can be used for something else.[2] The body uses it for moving its muscles, thinking, and breathing; for body heat, and for the many other processes necessary to maintain life.

[1] This burning of the tissue substances in the body is a process of oxidation. Every chemical combination which takes place with violence enough to cause heat is called combustion. Free oxygen has so strong an affinity for the carbon and hydrogen of the tissue substances that when it is brought in contact with them under proper conditions it tears them away from their union in these organic compounds, and unites them with itself. This union causes heat, and is therefore called combustion. In thus taking these elements for itself it breaks up the substances in which they are contained.

In the burning of wood or coal in the air we have merely the union of the elements of these substances with oxygen; and in the burning, as you have often seen, the wood or coal is broken up, its constituents becoming smoke and ashes, and its energy being liberated as heat. When we provide a fire in a furnace or stove with a draft we are simply seeing to it that the wood or coal secures plenty of air from which to get the oxygen for burning.

[2] This energy may be likened to a string which is holding together a bundle of fagots. When the string is broken or untied, the bundle falls apart, and the string can be used for other purposes.

About four fifths of the energy of the body goes to heat, one fifth to work.

The free oxygen for the body combustion is supplied from the air by the act of breathing. In the lungs the oxygen is separated from the air by the blood and conveyed by this blood to the tissues. Here it is united in the combustion as we have described.

Repair and growth. It is clear, then, that life itself and the processes necessary to the preservation of life, the many acts and functions of the body, are kept up in the body by the constant burning of the tissues. This burning causes a wasting of these tissues, a waste which is being constantly replaced by new tissue. This constant supply of repair material is derived from the food. The food, then, serves to keep intact the structure of the tissues and also their store of energy.

In the adult this supply of essential material and energy which the tissues derive from the food is practically that which is used up in the burning and the work.[1] The tissue which is burned is renewed, but no great amount of extra tissue is built. If a man works very hard he may use up more tissue than can be renewed at the time, and he loses weight; but with rest the renewal will be more rapid than the waste, so that he will regain this weight.

During the years of active growth, however, the cells of the tissues take up more material than they break down, and this goes to the formation of new tissue. The bones and brain and heart thus grow larger until they have reached the size which they are to keep through life.

The body a very perfect machine. In thus getting the material for the structure and repair of its various parts and the energy for its running from one and the same

[1] Some fat tissue may be built during adult life, also muscle tissue, but the framework of the body and separate organs remains fixed.

source, from the food, the body is at once a more economical and at the same time more perfect machine than any fashioned by man.

For all these are first built of iron and wood and other materials, and then get their energy by the burning of coal in their furnaces, or from a waterfall, the wind, electricity, or elsewhere; that is, they get their building material from one source and their energy from another. As they work, their parts wear out, until finally the machine has to cease work for repairs.

But the living body never has to cease work. It is always breathing; the blood is always flowing. The wear of tissue is replaced while the work is going on, from the food which is taken in. The best engine can use only one eighth of the energy liberated in its furnaces for work, while the body can use one fifth.

Metabolism. This whole process of the transformation of food to tissue and tissue to waste in the body, which results in maintaining the integrity of the tissues and the liberation of energy, is called *metabolism* (Greek *metaballo,* "I throw to and fro"—"change"). The body builds up (anabolism) and breaks down (katabolism), and the whole combined process is metabolism.

Division of function. Organs. The accomplishment of all the processes necessary to keep up this metabolism, such as the mental processes and movements which are necessary to procure food, the processes of digestion which prepare it for use by the cells, the distribution of the food about the body, the disposal of the waste, the supplying of free oxygen to the body, is divided among various body structures known as *organs* (Greek *organon*, "an instrument"). Thus, the brain controls the thought processes, the muscles control the motion, the stomach and intestines control the digestive processes, and the kidneys and lungs control the disposal of waste.

The work which each organ has to accomplish for the good of the whole body is called its *function* (Latin *fungi*, "to discharge an office").

Physiology. The study of the functions of the body and of its separate organs is called *physiology*[1] (Greek *phusis*, "nature," and *logos*, "discourse"). Upon the knowledge which we obtain by this study of the structure of the body, anatomy, and of the functions of the body, physiology, we base our knowledge of the laws and conditions of health.

Hygiene. The science of these laws of health is called *hygiene* (Greek *hugieia*, "health").

THE OBJECT OF THE STUDY OF PHYSIOLOGY AND HYGIENE

If a man knows the laws which govern the development of the human body and its maintenance in a condition of health, and follows them, he will, unless influenced by conditions beyond his control, grow up strong and well, and capable for the service of his community or country.

If, on the other hand, through ignorance or neglect, he fails to follow these laws, he will never attain the strength which might have been his, will more easily contract disease, and will be less able to keep up in the race with his wiser fellows.

Every one should therefore be familiar with the make-up of the body and with the functions of its various organs. Every one should know what the substances are which the body needs for its nutrition and work, and how it uses them;

[1] Broadly speaking, physiology is the science which treats of the phenomena of living bodies. The fundamental differential characteristic of a live body or substance is the possession of the capacity to build or form new substances from totally different materials. Thus, the human body changes bread and water, etc., into bone and flesh; the plants change or build up carbon, oxygen, and nitrogen to wheat and corn. They are thus live things. The single cells of the animal or plant body perform these changes, and they are thus live things. There are animals which consist of a single cell similar to these body cells. These cell creatures float about in water, eat food, and grow as the higher animals do. Lifeless things, as stones or bricks, are made of the same substances as live bodies, but they cannot form new substances from old, like living things.

why he eats and drinks, why he exercises, why he needs pure air. With this knowledge he can choose for eating and drinking those substances which are useful for nutrition, growth, and work, as milk, eggs, meats, grains, vegetables, and fruits, and avoid the use of those which may hinder these processes, as alcohol and tobacco. He can adopt those habits of life which tend to strengthen the body structures, as exercise, living in the open air, cleanliness, and can avoid undue exposure or fatigue, which makes him liable to disease.

It is of great importance that this knowledge be acquired in youth, for at this period the tissues are developing and taking their form; and any failure to provide the necessary food or any injury to the tissues at this time may result in a permanent deformity of the body. Thus, a boy who interferes with the development of his tissues by the use of tobacco must carry these undeveloped parts all his life, as they cannot grow after the period of growth and formation is past. The child who through poor food becomes rickety (rachitic) and gets deformed bones carries these bones to the grave. The boy who walks with bent shoulders while the bones are forming will be round-shouldered for life, as the shape of the frame is fixed in youth.

Health and disease. While every part of the body is sound and each organ performs its work perfectly, the condition known as health is maintained. When, however, any part becomes disabled, or the functions of the organs are not properly performed, the body is said to be diseased.

The causes of disease are very numerous. If the body is not supplied with a sufficient amount of food it may become diseased. Many diseases are due to parasites, small animal or vegetable organisms which get into the body and grow there, taking the food from the tissues and destroying them. Others are due to chemical poisons, which affect the functions of the organs.

Diseased conditions are also due to external injury, as a fractured bone or a cut with a knife. Some are due to exposure to cold. Some of these diseased conditions, as those due to starvation, improper feeding, or the taking of poisons, we can directly prevent by avoiding the causes. Those due to certain parasites which are carried from person to person in water, as typhoid fever and cholera germs, we can prevent by sanitary regulations. Other diseases, however, as those due to injury from without or to parasites which are carried through the air, we cannot so successfully ward off.

The first class are sometimes called preventable diseases, in contrast to the others, which are more or less accidental. But all diseases are to a certain extent preventable if we but understand their nature and the nature of the human body which they affect.

Every one cannot be expected to understand the nature of disease. That must at present be left to the physicians and the boards of health. But all can understand the nature of the human body, and the laws which govern its maintenance in health.

Through this understanding people will be able to protect themselves to a certain extent against all diseases. For all diseases are less likely to affect people who keep themselves in good condition, and more likely to affect those who have neglected to do so. Thus, a man who is fatigued by overwork, or one who has been exposed to cold, or one who has injured his organs or their function by poison or neglect to exercise them, is more liable to contract pneumonia or scarlet fever than a sound man, or more likely to have trouble in healing a wound.

The observance of the rules of health is therefore a great preventive of disease.[1]

[1] In China, it is said, physicians are paid a yearly salary to keep their patients in health. We must learn to keep in health through our own knowledge.

DEMONSTRATIONS AND EXPERIMENTS

TO FAMILIARIZE THE PUPIL WITH THE GENERAL FUNCTIONS OF ANIMAL LIFE

1. Measure your height and weight at the beginning of your school year, and record the results.

Take these measurements from time to time during the school year, and mark the variations, if any.

2. Take the temperature of the body by placing a clinical thermometer beneath the tongue for three minutes.

3. Place your finger upon the wrist over the radial artery (under direction), and note the regular "beat" of the blood stream flowing to the hand. Note the same beat in the temporal artery at the side of the head. Place the fingers between the fifth and sixth ribs on the left side of the chest, about two inches from the breastbone, and note the beat here of the heart thumping against the chest walls.

4. Measure the circumference of your chest with a tape, while breathing normally. Expand your lungs fully and, holding the breath, measure the circumference of the chest again.

5. Count the number of respirations in a minute.

COMBUSTION OF ORGANIC MATTER

6. To show the similarity between the combustion of organic matter which goes on in the body in the oxidation of the organic tissues and that outside of the body in the burning of any organic substance, as tallow, perform the following experiment:

Place a little lime water in the bottom of each of two bottles. Lower a lighted candle into one. When it goes out stop the mouth of the bottle and shake it.

Place a glass tube in the lime water of bottle No. 2 and blow through it. In both bottles the lime water will become cloudy, owing to the carbon dioxide which it receives in the first instance from the burning of the tallow, in the second from the burning of the body tissues.

QUESTIONS

I. What is physiology? (See note, p. 31.) Name some lifeless objects. Name some live objects. What is the real difference between

the living and the lifeless objects? Are there any lifeless objects which move about? Name some. What is the source of the heat energy which forms the steam and thus drives the locomotive? How is the energy formed which keeps the human body going and which enables man to work?

II. What is the effect upon the wood of burning it in a furnace? What is the effect upon the cells and tissues of the body of the burning of their substances? How is this constant wasting and wear of the tissues made up; that is, how is the loss from burning replaced?

III. What are the two objects of eating food? What turns the wheat and vegetables into bone and muscle? Where does the food get the energy which is stored up within it? How is this energy liberated in the body? Into what is it changed in the body? What is the source of most of the energy which the plants or animals store up?

IV. What becomes of the energy stored up in coal when this is burned in the open air? in the furnace of an engine which is running? What is meant by oxidation? Does this occur outside the body? Where does the oxygen for the process come from when the oxidation occurs in a furnace? Where does it come from in the body?

V. What is metabolism? How is the body a more perfect machine than a steam engine? What are organs? Name several. What is hygiene? What is the direct object of the study of physiology? Why should this study occur at an early age?

VI. What is disease? What is the broadest rule for the prevention of disease? What is the general aim for which all the organs of the body work together? Where in the body is the real vital center of life and activity? Whenever you lift a weight the energy for this action is supplied by combustion: in what tissues of the body does special combustion during this muscular effort occur? In what part does special combustion occur when you perform a mathematical problem in your head?

The skeleton.

CHAPTER III

THE SKELETON—THE BONES AND JOINTS

THE body is built up upon a solid frame, known as the *skeleton* (Greek *skello*, "I dry").

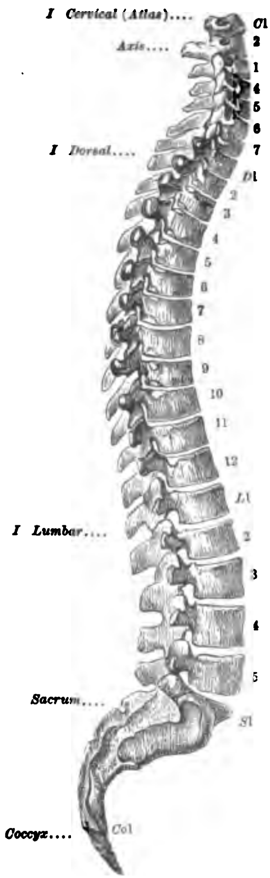
This skeleton is a very wonderful structure. It gives the body its shape and height and support. At the same time it is so put together as to allow one part to move upon the other in the many motions of the body.

It is made up of firm structures, called *bones*. These bones are the very best substances of which a movable frame like that of the body could be made, as they are very strong, light, and elastic. You can gain some idea of their strength when you are told that they are twice as resistant as solid oak.

The separate bones are built up together like the beams and pillars of a house. They are united by *joints*. In some cases these joints are firm, like those of the house beams. In other cases they are loose, like the joint of a boom and a mast upon a boat. These loose joints allow of motion of one bone upon the other and are called *movable joints*. The bones are sometimes joined together by plates of an elastic substance called *cartilage* (Latin *cartilago*, "gristle"). This is very elastic and allows the structure in which it is built to bend to pressure and blows. There is a great deal of this cartilage in the walls of the chest, and you all know how these walls, especially at the lower part, can be pressed

in, and how they spring back again. At the joints the bones are often held together by strong bands, known as *ligaments* (Latin *ligare*, "to bind").

The *number of bones* used in the body frame is more than two hundred. They are of many shapes and sizes, these characteristics depending upon the uses for which they are intended. Thus, in the limbs, where extended motion is necessary, the bones are long and slim. In the head, where protection is required, they are flat and firmly built together.



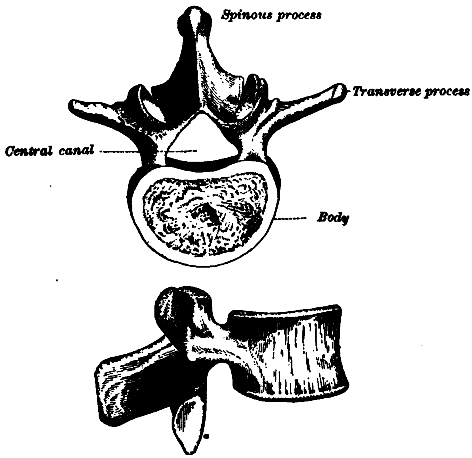
Vertebral column.

The general arrangement of the skeleton. The central portion of the skeleton, upon which all the other parts are supported, is the spine, or *vertebral* (Latin *vertere*, "to turn") *column*. Upon the top of this column rests the skull. At its sides are attached the ribs, which make the walls of the chest and support the skeletons of the upper limbs. At its base are attached the pelvic bones, which support the lower limbs.

The spine (Latin *spina*, "a thorn"). The spine, or backbone, consists of a number of small bones called *vertebræ*, placed one upon another in a column. There are thirty-three vertebræ in all. The first twenty-four are separate; seven cervical (Latin *cervis*, "neck"), twelve dorsal (Latin *dorsum*, "back"), and

five lumbar (Latin *lumbus*, "loin"). Below these come five more united into one bone, the sacrum, and below this four more united into the coccyx.

These vertebræ are all alike in general form. Each vertebra consists of a somewhat circular bone, flat at both ends, about one and one half inches in diameter by one inch in thickness, called the *body*. The body bears upon the dorsal (posterior) side an arch of bone, the *neural* (Greek *neuron*, "nerve") *arch*, and from the walls of this arch project three processes, a *spinous process* posteriorly and two *transverse processes* laterally. The vertebræ lie one upon another in a column. Each is separated from those next it by pads of *cartilage* about a quarter of an inch in thickness.



Vertebræ.

These cartilage pads are called the *intervertebral disks.* They bind the vertebræ together, serve as a cushion to prevent one vertebra striking upon another, and by their elasticity allow of a certain amount of motion of each vertebra, and thus of the whole vertebral column.

The upper surface of the arch of one vertebra touches the lower surface of the arch of the one above, forming joints at the points of contact.

At the front of the vertebral body and at the back, and at the junctions of the arches, are *ligaments*, which bind

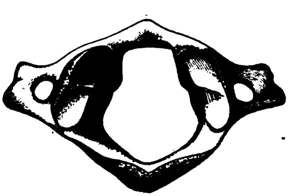
the bones together. Ligaments also attach the spinous processes.

As the arches of the vertebræ thus lie together in a line they form in their center a continuous canal bounded by bone and ligament. In this canal runs the delicate nerve structure which takes the messages from the brain to the organs and limbs, the spinal cord.

This spinal column is really a very wonderful contrivance. It is made up of a chain of little bones so strong that it will support the whole body and any weight which it may carry, and yet so flexible that it bends like a willow rod, and takes the shock of running and leaping so easily that none of the jar gets to the brain, which lies in a case on its top. In its center it carries safely through years of bending and twisting a delicate nerve cord which the least pressure would injure.

The column is curved. At its upper part in the neck it arches forward; in the back it curves backward; lower down in the loins it runs forward again, and at the base backward again. This curved form, together with the cartilaginous cushions between the vertebræ, gives a springiness to the spine which prevents jarring.

If you drive a strong straight stick down upon the sidewalk you get a shock in the hand, but if you do the same thing with a curved stick of the same strength, as half a hoop, you receive very little shock. The same principle holds true of the spine.



Atlas.

The arrangements of intervertebral attachments and joints of the column allow a slight forward and backward motion, a slight lateral motion, and even some twisting of one vertebra upon another. Thus we can bend forward or backward or sidewise, or twist about.

The first cervical vertebra is called the *atlas* (after Atlas, the Titan supposed by the Greeks to support the world). It differs in form from the other vertebræ. It is shaped like a ring without any body. Upon its upper surface are two smooth surfaces upon which the skull rests.

The atlas rests upon the second vertebra, the *axis*. The axis has a process, the *odontoid* (Greek *odous*, "tooth," and *eidos*, "resemblance") *process*, which fits into the ring of the atlas and forms a pivot on which the ring revolves.

The skull, atlas, and axis are bound together by ligaments in a set of loose joints which allow the free motion of the head. The skull moves backward and forward upon its joints with the atlas, the atlas being held firm on the axis. When the head moves around, the atlas moves with it, rotating upon the pivot process of the atlas. Two ligaments from the odontoid process to the skull check this rotary motion.

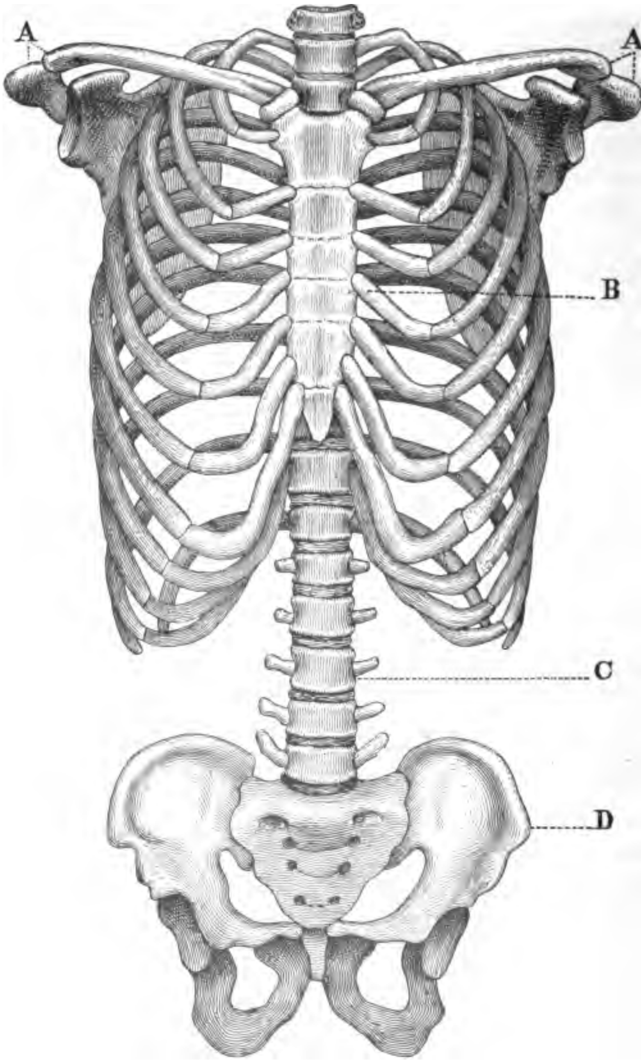
Sacrum, made of five vertebræ.

The *sacrum* lies at the base of the column. Its five vertebræ are grown together into one bone in the adult. It supports the pelvic girdle. Below it carries the *coccyx*, which consists of four vertebræ formed into one bone.

The thorax. Attached to the dorsal vertebræ are the ribs. With the sternum, which they support, these ribs make the walls of the *thorax* (Greek, "chest").

The *ribs* are twelve in number. Each rib attaches to a dorsal vertebra by one joint with the transverse process. Most ribs also attach to the vertebra above their main one.

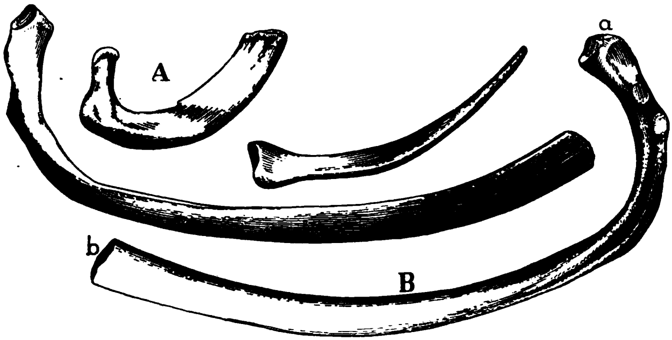
From the spine the ribs sweep round and a little downward



Skeleton of trunk.

***A*, *A*, scapulæ and clavicles forming pectoral girdle; *B*, ribs and sternum forming thorax; *C*, vertebral column; *D*, pelvic girdle.**

to the front of the thorax to attach by their cartilages to the sternum. Upon each side seven ribs attach separately. The next three connect with one another, and all together



Ribs.
A, short upper rib; *B*, long median rib; *a*, vertebral attachment; *b*, attachment of cartilage which joins to sternum.

attach to the seventh rib. The two lower ribs have their forward end unattached and are called *floating ribs.* Each rib consists of a flat bone, with a flat cartilage, called a *costal cartilage* (*costa*, "a rib"), upon its sternal extremity.

The joints of the ribs, with the vertebræ and with the sternum, allow of the motion between these parts which occurs in breathing.

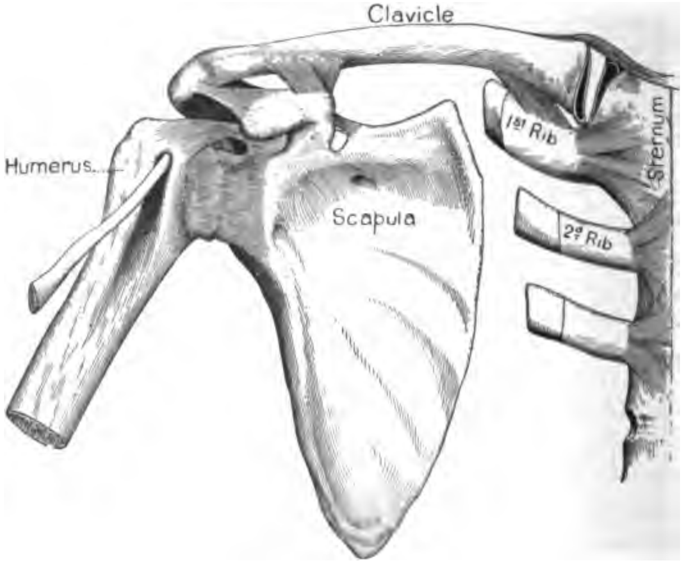
The combination of bone and cartilage in the ribs, their curved shape and jointed attachments, make them excellent structures for the movable walls of a box like the thorax, which must be, at the same time, strong, light, and springy.

The *sternum* (Greek *sternon*) is a flat bone forming the frontal piece of the thorax. It is attached to the seven upper ribs.

The pectoral and pelvic girdles. Attached to the spine and thoracic skeleton are the two girdles which support the limbs.

The *pectoral girdle* (Latin *pectus*, "chest") consists of two attached bones upon each side of the thorax, the *clavicle* (Latin *clavis*, "a key") and the *scapula*.

The *clavicle*, or collar bone, articulates at its inner extremity with the sternum. At its outer extremity it supports



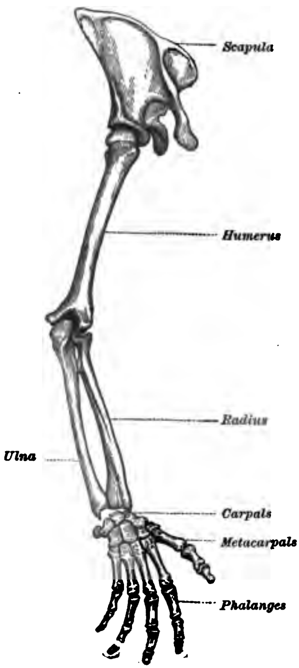
Scapula and clavicle, with end of humerus, representing articulation of pectoral girdle with thorax.

the scapula. It holds the arm out from the body and thus facilitates free motion. In animals, as the horse, which use the fore limb for support only there is no clavicle in the skeleton.

The *scapula*, or shoulder blade, a large flat triangular bone with a prominent spine upon its dorsal surface, lies behind the ribs in the back. It is held in its place by muscles and ligaments, and by its attachment to the clavicle. Together

these bones, two upon each side, form an imperfect arch for the support of the arms.

The *pelvic* (Latin *pelvis*, "a basin") *girdle*, which supports the lower limbs, is made up of the two *innominate* (Latin *in*, "without," and *nomen*, "a name") or hip bones, one upon each side. Each bone attaches to the sacrum and arches round to meet its fellow, the two together forming a complete arch. The cup-shaped cavity thus formed is called the *pelvic cavity*.



Arm.

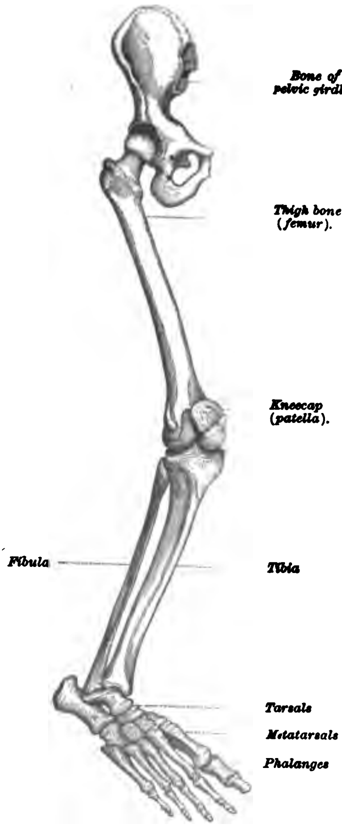
The skeleton of the upper limbs consists of a series of bones.

The *humerus*, a long bone, articulates with the scapula by a ball-and-socket joint. At the other end of the humerus two bones, the *radius* (Latin, "a spoke") and *ulna* (Latin, "elbow"), articulate with it, forming the elbow joint. These two bones, which form the skeleton of the forearm, run parallel from the elbow to the wrist.

The *wrist* is made up of eight small *carpal* (Greek *karpos*, "wrist") bones, which articulate with the lower extremity of the radius and with one another, forming the wrist joint and the lower part of the hand.

To these bones are attached the *metacarpal* (Greek *meta*, "after," and *karpos*, "wrist") bones of the hand, and to these the first *phalanx* (Greek, "battalion") of each finger and thumb. Each finger has three phalanges, one articulating

to the end of the other. The thumb has two. The fingers are shaped and put together in the hand in a way to allow their doing various and delicate tasks. Their varying length makes them fit perfectly into the hollow of the hand.



Leg.

These bones are all articulated by joints and attached by ligaments. They are so arranged as to allow of a very free motion.

The skeleton of the lower limbs corresponds in its general plan with that of the upper.

The *femur,* corresponding to the humerus, articulates with the pelvic girdle. To the femur articulate the *tibia* (Latin *tibia,* "a flute or pipe") and *fibula* (Latin, "a buckle") at the knee. Seven *tarsal* (Greek *tarsos,* "instep") bones, which articulate with the tibia and fibula and with one another, make the ankle and beginning of the *foot.*

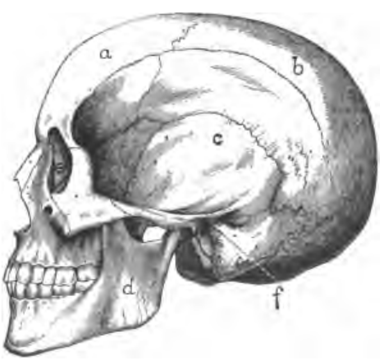
To the tarsals are appended the *metatarsals* (Greek *meta,* "after," and *tarsos,* "instep"), and to these the *phalanges,* two for the big toe and three for each of the others.

In addition to these bones the skeleton of the lower limbs includes the *patella* (Latin *patina,* "a pan"), or kneecap, a

small bone which lies in the tendon of the muscles which extend the leg.

The *formation of the limbs is adapted to their function.* Since the chief function of the limbs is extended motion, they are made up of long bones articulated by joints which allow very free motion. Lightness and strength are combined as far as possible in the bones. As the arm and hand are used for reach and prehension, the joints are very free. The leg, being used for support as well as motion, is more firmly bound to the trunk, and the joints are less loose. The small bones of the foot and ankle are arranged in the form of a springy arch to carry the body more easily in locomotion. The marked differences between the two sets of limbs are seen only in man and the monkeys, as it is only in these animals that the two sets are used for such different purposes.

The skull, or skeleton of the head and face, rests by its posterior bone, the occipital bone, upon the upper bone of the spine, the atlas. It is composed of twenty-eight bones. Eight of these form the cranium, six the ears, and fourteen the face. The *cranium* is a box for the protection of the brain. It is composed of a basal *occipital* (Latin *ob*, "against," and *caput*, "head") *bone*, which rests upon the spine; two *parietal* (Latin *paries*, "a wall") bones, one on each side, forming the crown; two *temporal* (Latin *tempora*, "temples") bones, one on each side; a *frontal* (Latin *frons*, "forehead") bone, forming the



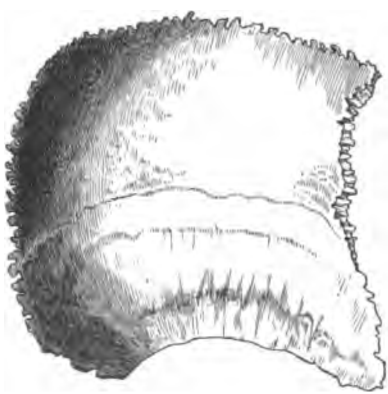
Skull.

a, frontal bone; *b*, parietal; *c*, temporal; *d*, lower jawbone; *e*, eye socket; *f*, canal of ear.

forehead; a *sphenoid* (Greek *sphen,* "wedge") bone at the base, with an *ethmoid* (Greek *ethmous,* "sieve") bone in front of it.

Foramina (Latin *foro,* "bore a hole"). In the occipital bone is a large opening, the *foramen magnum,* through which the spinal cord enters the spinal canal. In the temporal bones are the openings to the ear cavities. Openings for the passage of the cerebral nerves occur in several of the bones. These apertures are called *foramina.*

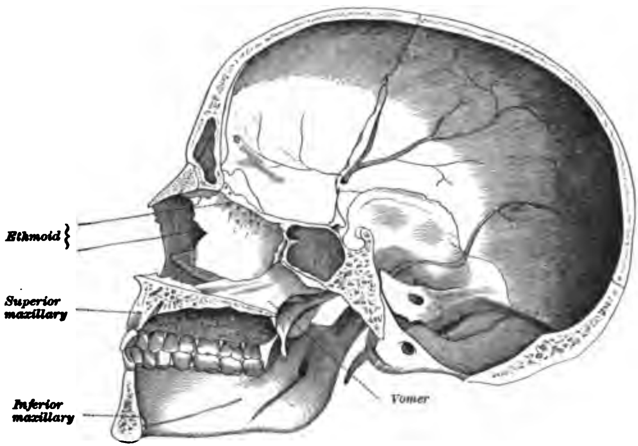
As the object of the cranium is protection, the bones are firmly united to one another by immovable joints, called *sutures* (Latin *suere,* "to sew"). In these sutures the edges of the bones are for the most part dovetailed, the projections of one bone edge fitting the hollows of another. The sutures can be easily felt upon a baby's head. The bones are hard and thin, and are placed together to form an arch. The character of these bones and this method of their arrangement make the cranium an excellent shield to prevent the shock of blows from reaching the brain. The skull is so shaped that the strongest point is in front, just where the danger of a blow is greatest. The skull is so firm and hard that bullets sometimes glance from it as from armor.



Bone of cranium, showing serrated edges.

The Face. The bones of the face articulate with the cranial bones and with one another. They consist of the *malar* (Latin *mala,* "cheek") or cheek bones; the *maxillæ,* or

upper jawbones, which carry the upper teeth; the *palate* (Latin, "palate") bones, which together with the maxillary form the roof of the mouth; the *nasal* (Latin *nasus*, "nose") bones, roofing the nose; the *lachrymal* (Latin *lachryma*, "a



Vertical section of skull.

tear") bones, lying between the nasal and orbital cavities; the *turbinate* (Latin *turbo*, "a top") bones, the *vomer* (Latin, "a plowshare"), and the *inferior maxillary* or jawbone.

The upright character of the human skeleton. The human skeleton is fashioned for an upright bearing. The head is nearly balanced upon the vertebral column, so that it takes very little muscular effort to hold it erect. The pelvis is broad, so that the balance of the trunk upon the lower limbs is easily maintained. The spine is curved and elastic, thus preventing the forcible transmission of the impact of the feet or hips with the earth to the head and brain. The attachments of the lower limbs to the trunk are very firm, thus allowing a secure support of the body in standing and locomotion. The instep arch of the foot is firm and springy,

preventing the occurrence of shock when the feet strike the ground.

Man a vertebrate animal. The presence of the spinal column, dividing the body (trunk and head) into two cavities, —a front or ventral one, which contains the lungs and stomach and heart, and a posterior or dorsal one, containing the organs of the nervous system,—places man in the class of animals known as vertebrates. To this same group belong the fishes, reptiles, birds, and beasts. Clams, insects, worms, and other lower forms possess no backbone and are called invertebrates. Man belongs to the special class of vertebrates known as mammals, animals which suckle their young, which have more or less of the body surface covered by hair, and which have the ventral cavity of the body entirely separated by the diaphragm into the thoracic cavity and the abdominal. Beasts, as the monkey, the dog, etc., possess the same organs and parts in their bodies as man. The brain of man is, however, much more highly developed than that of any beast. He possesses a mind which makes him sensible of right and wrong and enables him to reason. It is these qualities of mind which make him supreme among living things.

DEMONSTRATION

The pupil should visit some museum and look at the skeleton of a man, also at those of monkeys and of fourfooted beasts. Note the various resemblances in the parts and general structure of the skeletons.

THE JOINTS

The bones of the skeleton are placed together by means of *joints*. The joints may be immovable, as the joints of the cranial bones, or movable, as those of the arms and spine.

The *movable joints* are contrivances which allow and regulate the motion of the bones upon one another, and thus the movements of the body.

The motion is secured through the agency of the muscles, which work the bones one upon another in these joints, just as the rope (sheet) attached to the boom of a boat pulls the boom about upon its joint with the mast.

Structure of a movable joint. The ends of bones which meet in a joint are covered with cartilage, which provides a smooth, elastic surface for motion and pressure. These cartilages are made thickest upon the middle of the convex surfaces and upon the edges of the concave surfaces, that is, just in the places where the wear is greatest. The bones are held together by ligaments, which lie above the joint. With the muscles they keep the bones in place and limit the motion of the joint.

Joint.

1, right hip, exterior, showing capsule ligaments; 2, left hip, showing interior of joint.

One ligament forms about the ends of the two bones, inclosing these ends and the joint in a closed sac. This sac forms the *capsule* (Latin *capra*, "a box") of the joint.

On the inside of the capsule is a thin membrane, the

synovial (Greek *sun*, "together," and *oon*, "egg"—a fluid like white of egg) *membrane.* This secretes a fluid which pours over its surface and keeps the joint lubricated. (See Experiment 9, chapter on motion.)

Forms of joints. The joints differ in their formation in accordance with the kind and amount of motion which is to be secured. Thus, we find ball and socket joints, allowing of a to-and-fro, in-and-out, and rotary motion, as the shoulder joint; hinge joints, as the elbow, allowing a backward and forward motion like that of a door; gliding joints, as those between the vertebræ; pivot joints, as that of the atlas and axis, allowing rotation.

Ball and socket joint. In the shoulder joint the rounded upper extremity of the humerus fits into a shallow, cuplike *fossa* (Latin, "a ditch") of the scapula. The joint is surrounded by a loose capsular ligament and external ligaments which hold the humerus to the scapula.

Most of the movements of the whole arm take place in this joint, which is very free. Thus, the arm can be carried forward and inward, that is, flexed (Latin *flexere*, "to bend"); or carried backward and outward, that is, extended (Latin *ex*, "out," and *tendere*, "to stretch"); or carried toward the midline of the body, that is, adducted (Latin *ad*, "toward," and *ducere*, "to draw"); or away from the midline, that is, abducted (Latin *ab*, "away from," and *ducere*, "to draw"); or twisted round in its joint, that is, rotated (Latin *rota*, "a wheel"); and so forth.

The joint is made very shallow to allow the very free motions of the arm. This shallowness accounts for the frequent dislocations of the shoulder.

The hip joint is another ball and socket joint. Here, however, a firm support is needed, and so the joint cup is deeper and the ligaments are more firm. This joint is so tight that the air pressure aids in keeping it in place.

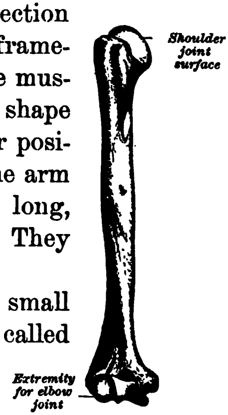
The *elbow* joint is a *hinge* joint, allowing simply flexion and extension. In this joint the radius and ulna move upon the rounded end of the humerus. The ulna fits to the humerus much as a boom fits to a mast. By this arrangement no side or rotary motion is possible. Flexion is limited only by the pressure of the muscles coming together. Extension is checked by a ligament in front of the joint.

The knee joint is on the same plan, but has larger cartilages and firmer ligaments, as it is used for support as well as motion.

The motions of the forearm are regulated by the action of the parallel bones, the radius and the ulna, upon each other. The radius is attached to the ulna by two pivot joints, one above and one below. It can be rotated upon the ulna, and as it carries the hand, this turns forward and backward with the radius, performing the motions of pronation (Latin *pronus*, "on the front") and supination (Latin *supinus*, "on the back"), that is, the motions of turning the hand upon its front or upon its back.

Forms of bones. The *bones* are hard, firm structures. Their function is support of the body, and protection of the soft parts which lie within their framework. Many of them form levers for the muscles to act upon in producing motion. The shape and character of the bones differ with their position and use in the body. The bones of the arm and leg, as the humerus and femur, are long, slim, and hollow, with clubbed extremities. They are called *long bones*.

The bones of the wrist and ankle are small rectangular or polygonal bones. They are called *short bones*. The sternum is a *flat bone*. The ribs are flat or tabular bones. A rib consists of a thin plate composed of hard



Long bone.

surface layers and a very small layer of spongy bone substance between (Experiment 4).

Other bones, as the vertebræ, combine the characters of two or more of the above forms, and are called *irregular bones.*

The chemical composition of bone. The bones must be hard and at the same time tough. They must be firm enough not to bend, and yet flexible enough not to break with weight. To attain this combination of hardness and toughness the bones are made up of a compound of two substances. One, the mineral or inorganic substance, consisting principally of phosphates and carbonates of lime, gives the hardness. The other, the organic substance, gives the toughness and elasticity.

If a bone be burned in a hot fire all the organic matter will be separated and the mineral matter left. It will have lost its toughness, and will break at a blow or crumble beneath the fingers.

If a bone be soaked in dilute hydrochloric acid all the mineral matter will be separated and the organic matter remain. The bone will then be flexible, bending double without breaking, and so useless for support. (See Experiments 5 and 6.)

In infancy and childhood the bones are not so hard as in adult life. They contain more of the organic matter, which makes them bend more easily. This accounts for the fact that children's bones are less likely to break with falls.

Gross structure of bone (Experiments 1–3). If we examine a fresh long bone, as the humerus or femur, we see that it is a long cylindrical shaft with two large articular extremities. If we lift it we find that it is much lighter than it looks. Upon the surface of the shaft is a tough membrane composed of connective tissue and blood vessels—the *periosteum* (Greek *peri*, "around," and *osteon*, "bone"). This periosteum

is the nourishing membrane of the bone. Upon its inner surface the deposit of new bone occurs in the growth of the bone. If it be stripped away the bone dies.

The articular surfaces of the extremities of the bone are lined with cartilage.

Internal structure. If we divide the shaft longitudinally we find that it consists of a thick, hard, compact outer layer, and a thin inner layer of spongy tissue, looking like a trelliswork of fine bony process surrounding a hollow central cavity. This central or *medullary* (Latin *medulla*, "marrow") *cavity* runs throughout the shaft. It is filled with soft yellow marrow. In it run blood vessels, lymphatics, and nerves to supply the bone.

Section of a long bone.

The tissue of the articular extremities is composed of a mass of spongy substance filled with red marrow and coated by a thin layer of hard, compact bone.

This combination of hard, compact exterior with a reticulated interior formation and a hollow center gives the bones great strength with small weight. If the bones were solid throughout they would be much heavier and less strong, as a tube will bear more weight than a rod containing the same amount of material.[1]

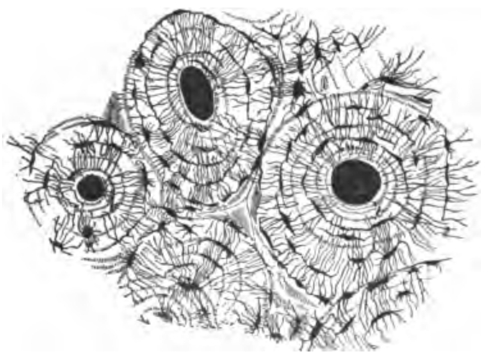
The flat bones of the body have the same general structure, but possess no hollow centers. This spongy trelliswork formation keeps the bone from jarring with the shock in falls. In animals like the alligator, whose recumbent posture protects them from falls, the bones contain much less of this spongy structure. The *trabeculæ* (Latin,

[1] This principle is utilized in the construction of tubular bridges. In birds the hollow of some bones, instead of marrow, contains air, being connected with the lungs. This secures greater lightness than that of human bones.

"small beams") of the trellis tissue are arranged in arches to support the weight which the bone has to bear.

Histological structure of bone (Greek *histos*, "tissue," and *logos*, "discourse"—study of tissue). Histologically the bone is made up of a collection of cells and their processes, and intercellular substance in which lime salts have been incorporated.

Examined under the microscope even the densest part of the bone proves to be simply a fine network of small bony plates and fibers. Throughout this network run canals, the *Haversian canals*, carrying the blood vessels for the nourishment of the tissue. These canals open at the periphery (Greek *peri*, "about," and *phero*, "carry"—outer surface) and in the medulla. Around the canals in concentric lines, consisting of a series of plates, are the *lamellæ* (Latin *lamina*, "a plate"), which form the walls of the fine network. Each canal and its lamellæ form a *Haversian system*, and the network is made up of these systems.



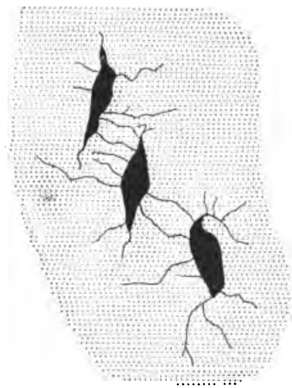
Haversian system of bone.

Dark central canals surrounded by lamellæ and the dark lacunæ with caniculi extending across the direction of the lamellæ.

Between the lamellæ, in a circle round the canals, are small cavities known as *lacunæ*, from which radiate fine tubes, the *canaliculi*, opening into the Haversian canals, or into the canaliculi of other lacunæ. In each lacuna lies a living cell. These cells are the bone cells. The plates which make the

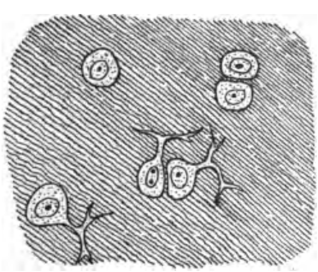
frame of the network are made of intercellular substance with deposits of lime salts. The bones are constantly growing, like any other tissue.

Structure of cartilage. Cartilage lines the articular surfaces of many bones, forming a smooth, elastic surface material for the joints (Experiment 1). It is also used in connection with bone or alone to make up certain parts of the skeleton. Thus, a part of the shaft of each rib is cartilage. It is a flexible, tough substance, somewhat like hard rubber, and thus gives flexibility to the parts in which it is used.



Bone cells.

In its intimate structure cartilage consists of a homogeneous (Greek *homos*, "like," and *genos*, "kind") intercellular substance with cells scattered about in it. Most of the bones begin as cartilage, in which bony tissue is afterwards deposited. This complete change of cartilage into bone, the *ossification*, does not occur in some bones until twenty years of age, and even later.



Cartilage.

Ligaments are tough, somewhat elastic bands composed of connective tissue. They are used to bind the parts of the skeleton, the bones and cartilages, together. They support organs. They form the supports and the sheath of joints. (See Experiment 9, p. 85.)

Connective tissue is a very widespread tissue in the body, entering into the formation of many parts and organs. Ligaments, the periosteum of bones, the fasciæ and tendons of muscles, are composed of it, and it enters into the walls of serous and mucous membranes and blood vessels and into the skin. Its texture may be very firm or very loose, according to its position or use.

HYGIENE OF THE SKELETON

The first requisite of a strong, agile body is a good bony frame. Strong muscles lose much of their efficiency if they do not have strong, straight bones to act upon. Any weakness or deformity of the bony walls of the body tends to restrict the growth and functional efficiency of the organs which are protected and supported by these walls, as are the brain and lungs.

Effect of good and bad habits upon the skeleton. • The ossification of the cartilage and the bony union of the shafts and extremities of the bones go on during infancy and childhood. Complete union is not accomplished until about the twentieth year. In thus hardening, the frame and the bones will tend to take the shape in which they have been allowed to grow. We should have care, therefore, that they are not influenced disadvantageously by improper habits.

Thus, a child should not be allowed to walk until his leg bones are capable of bearing his weight. Otherwise the flexible bones may bend outward and become fixed in this shape, and the child thus be bow-legged.

Children should carry the frame erect and the shoulders well back. The development of the thorax should be encouraged by running and rowing, and exercises with the arms. Thus a full respiratory capacity will be developed.[1]

[1] The correct position is: head up, chin in, chest expanded, shoulders back and down, abdomen in, hips thrown back. By holding this attitude in mind and prac-

Dress. All clothing which constricts the chest or waist, as tight waists or corsets or belts, should be discarded.[1]

Short skirts are better than long ones, as they allow a fuller development of the legs by permitting a freer stride.

Tight shoes permanently deform the foot, and, by thus influencing the gait, hinder the development of the legs.

Seats in schools. Much harm has come in past times from improper methods of seating children at school. The seat should be of such a height that the feet touch the floor, else the thigh bones may become bent by the weight of the legs below.

The desk should be so arranged that the child may sit erect while writing, to avoid the risk of a lateral curvature of the spinal column, or a stoop of the shoulders.

Food. The proper development of the bones is dependent upon proper feeding. In improperly fed children the bones do not harden as they should. There is a disease common among children of the poor, called *rickets*, in which great deformities of the bones occur as a result of the lack of proper food.

Fracture (Latin *frangere*, "to break"). When a bone is broken the injury is called a *fracture*. When this occurs a very interesting process ensues. From the broken ends of the bone a fluid substance oozes and collects about the fracture. In time this hardens to a gristle-like substance. Then bone begins to be formed in this substance, just as it does in cartilage in the original formation of bone, until in six

ticing it faithfully for a few days one can train the muscular sense to become accustomed to it, and after a time to feel uncomfortable in a stooping or crooked position. In sleep also the straight position should be cultivated, that the chest may have room for free expansion. Pillows should be only high enough to support the head at such a level as will hold the neck straight.

[1] It is said that the Queen of Portugal has amused herself and her friends by having pictures of the skeletons of the ladies of her court made by means of the X ray. These pictures showed the bones of the thorax so deformed, evidently by the use of the corset, that it made a decided impression on them, and they have determined to use this article of dress no longer.—Journal of Hygiene.

weeks the broken parts are united by new bone just as good as the old.

Dislocation. The joints are delicate structures. Their location subjects them to sudden and severe strains. In a fall, for instance, the whole weight of the body may come upon the wrist or shoulder. A misstep brings an unexpected strain upon the ankle. Owing to the loose structure of the joints, these strains are likely to lead to *dislocations* (Latin *dis*, "from," and *locus*, "place"). Thus, a baseball striking the end of the finger pushes the inner end of the phalanx through or past the ligaments, "out of joint." The bone has then to be put back over the same course by which it went out.

When the ligaments of the joint are stretched and bruised or torn, the injury is called a *sprain*. Such an injury often occurs from a wrenching of the ankle in running.

Exposure to cold and wet. The joints are a favorite seat of several diseases. Exposure to cold and wet is very likely to cause inflammation, and is often followed by a disease known as rheumatism, which frequently affects the joints.

Alcohol drinking. Indulgence in alcoholic liquors appears to have a distinctly deleterious effect upon the nutrition of the bones. It is a well-authenticated fact, substantiated by the testimony of many surgeons, that in alcoholic subjects (heavy drinkers) the repair of fractures and other injuries to bones is much less vigorous than in the average patient. The periosteum appears unable in such cases to supply the proper nourishment so rapidly as in normal condition.[1]

[1] As a surgeon having vast opportunities of experience in hospital and private practice, I must declare that I always look upon patients who have been in the habit of using spirituous beverages as least likely to recover from serious maladies or from shock following operations, and also as those most likely to require longer time for the cure of diseases of a more simple character. I have at times met with cases of fracture of the bones, occurring in persons of intemperate habits, in whom the bones would not unite by bony material, but remained flexible or useless.— J. N. Carnochan, Professor of Surgery, New York Medical College, author of Contributions to Operative Surgery.

Indulgence in alcoholic liquors is a very prominent factor in the causation of *gout*, with which is often associated a very serious diseased condition of the joints.[1] This disease is common among people who are accustomed to high living, and especially to drinking strong wines and ales. The tendency to gout is often inherited.

Faulty nutrition of the bones, from the use in youth either of alcoholic drinks or of tobacco, prevents their full development, and consequently affects the stature.[2]

DEMONSTRATIONS AND EXPERIMENTS

STRUCTURE OF BONE

1. Procure the thigh bone of a sheep, with the meat upon it. Remove the meat by soaking and scraping.

Note the pinkish-white color of the bone, which is due to the vascular parts of the tissue, from which all blood and lymph have not yet disappeared. Contrast this color of bone lately living with the white color of old dried bone.

Note the large, roughened ends of the bone; the smooth surfaces for articulation; the cartilage which lines these articulation surfaces.

Note the rough places for the attachment of muscles. Somewhere in the length of the bone you will find a hole, which is the entrance of a blood vessel into the bone.

2. Saw this bone across in the middle. Note the difference in the character of the compact outer layer and the "spongy" inner layer.

[1] There is no truth in medicine better established than that the use of fermented or alcoholic liquors is the most powerful of all the predisposing causes of gout; nay, so potent that it may be a question whether the malady would ever have been known to mankind had such beverages not been indulged in. Stout and porter rank next to wine in predisposing to gout; cider and smaller beverages will also act to some extent as producing causes of gout.— Dr. Alfred Baring Garrod.

[2] Children of alcoholic parents, trained to the early use of liquor, are stunted in their growth, and a French physician is inclined to ascribe to this fact the decrease in the standard of normal height shown by statistics in that country.—Journal of the American Medical Association, November 14, 1896.

Smoking prevents the healthy nutrition of the several structures of the body; hence comes, especially in young persons, an arrest of the growth of the body; low stature, a pallid and sallow hue of the surface, an unhealthy supply of the blood,

Note the central cavity with its contained soft marrow substance.

3. Make a longitudinal section of the lower half of the bone.

Note the archlike arrangement of the trabeculæ of the spongy tissue in the extremity of the bone.

4. Obtain a rib.

Make a cross section.

Note the difference in the structural plan of this flat or tabular bone and that of the long bone examined.

5. Composition of bone. Organic substance.

Weigh a rib bone. Heat it in a hot coal fire for half an hour.

Note and explain the changes which occur in burning.

After cooling, weigh again. The loss in weight is due to the loss of organic matter which has burned up. The shape of the bone remains the same, but there is less substance.

The bone is now easily breakable because the tough organic matter which gave it tenacity is gone.

6. Removal of mineral matter from bone.

Weigh a rib bone as before.

Add a teaspoonful of hydrochloric acid to a pint of water. Place the bone in this for a few days.

Note that the size and form do not change.

Note the loss of weight, after drying the bone thoroughly.

When it is taken out, note that the bone bends much more easily than before; that it can now be cut with a knife. This is because the hard mineral matter has been removed by the acid, leaving the tough organic matter only.

7. Test for the carbonates and phosphates in bone.

Pulverize some of the bone which has been roasted and add hydro-

and weak bodily powers.— James Copeland, M.D., F.R.S., Editor of London Medical Repository.

I believe that no one who smokes tobacco before the bodily powers are developed ever makes a strong, vigorous man.— Fergus Ferguson, M.D.

A record of the users of tobacco has been kept at Yale for the past eight years, for the main purpose of determining the number of men who began the habit while in college, and, from the uniformity of the records, considerable confidence has been felt in the results obtained. The growth of the men is as follows: In weight the nonusers increased 10.4 per cent more than the regular users, and 6.6 per cent more than the occasional users. In the growth of height the nonusers increased 24 per cent more than the regular users, and 14 per cent more than the occasional users.— Professor J. W. Seaver, M.D., of Yale, in the University Magazine.

Stunted growth has again and again impressed a lesson of abstinence from tobacco, which has hitherto been far too little regarded.— London Lancet.

chloric acid. Bubbles of carbonic acid gas will be given off. This test shows the presence of the carbonates.

Add water. Filter. Then to the clear filtered solution add ammonic hydrate. A precipitate will fall. This precipitate consists of phosphates.

8. Proportion of water and solid in fresh bone.

Break a fresh bone into small pieces. Weigh, dry in a current of warm air until there is no variation in the weight, and weigh again. Determine loss. The loss is water.

QUESTIONS

I. What is the function of the skeleton? What structures and mechanisms are used in its make-up, and how are they put together? Describe the general arrangement of the skeleton. How is the vertebral column built up? What is inclosed within the column? Give some idea of the adaptability of the spinal column to its uses.

II. What are intervertebral disks? Where is the atlas? What does it support? What keeps all the bones joined together? What is the lower end of the spine called? What is the thorax? What is contained within it? How many ribs are there? How are the ribs attached at each end?

III. What motions of the thorax do the joints and attachments between the spine and ribs allow? Why is part of each rib cartilage? Where does the sternum lie? What is the pectoral girdle? How is it attached to the trunk skeleton?

IV. Describe the scapula. What is the pelvic girdle? How do the humerus, radius, and ulna lie in relation to each other? How many bones are there in the wrist? Name the bones of the leg. What are the metatarsals? In what parts are the phalanges?

V. Give some idea of the way in which the structure of the limbs is adapted to their use. Describe the skull. What is the chief object of the cranium? What are foramina? How are the cranial bones jointed together?

VI. To what class of animals does man belong? What is a joint? Describe a movable joint in the body. Mention a ball-and-socket joint; a hinge joint. What are the functions of the bones? Name several varieties of bones.

VII. How is it accomplished that bones are both hard and tough and elastic at the same time? What happens when the inorganic substance is removed from a bone by acids? How do the bones of children differ

from those of adults? Give a general idea of the gross and finer structure of a bone, as the humerus. What is gained by having the long bones hollow?

VIII. Where in the body do we find cartilage? How does it compare with bone in hardness and elasticity? Of what kind of cell substance does cartilage principally consist? Does cartilage ever change in the body? What is ossification? What are ligaments used for in the body?

IX. When does the body take its shape? How does the knowledge in regard to the anatomy and physiology of the skeleton influence us in our habits of life? What is a fracture? What is a dislocation? A sprain?

X. If a man and a boy each sat daily for three or four hours in a straight-backed chair, which would receive the more injury? Is the same true of tobacco smoking? Why is a fall less likely to injure a child than a grown person?

CHAPTER IV

MOTION

I. THE MECHANISM OF MOTION. II. THE ORGANS OF MOTION

ONE of the very important functions of the body is that of motion. In providing for its wants the body must perform a variety of movements. It is moved from place to place by the motion of the legs. The arms are moved in supplying the food to the body. The lips, jaws, and tongue are moved in eating the food. The heart is constantly moving in pumping the blood. The food is kept moving in the stomach and intestines by motions of the walls of these organs.[1]

All these motions are brought about through the agency of a set of organs known as *muscles.*

These muscles form the firm flesh which we can feel beneath the skin and fat, covering and filling out the whole skeleton. They act for support and protection of the parts, but their prime function is motion. Wherever there is motion to be performed there are muscles provided for its performance.

Each muscle is a firm, fleshy body, which has the power of contracting, that is, of growing shorter. You can feel in

[1] Motion is one of the forms which the energy store of the body assumes when it is liberated. The burning of the tissue supplies, and consequent liberation of energy for this purpose, takes place in the organs adapted for the accomplishment of this function.

your arm the firm, fleshy muscle known as the biceps, and can feel it grow larger in girth and shorter when you contract it to bend your arm.

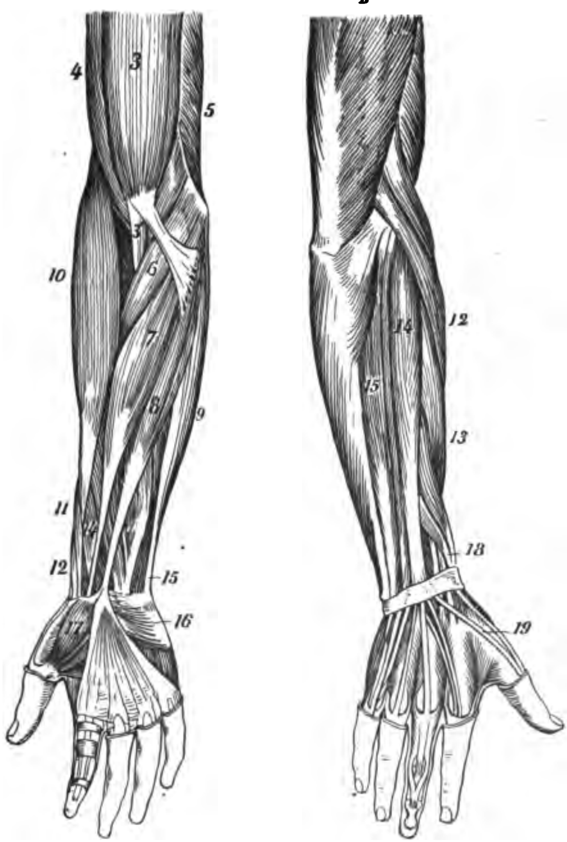
The muscle is often attached to bones, and by moving pulls one up toward another. Let us illustrate by this same biceps muscle. This muscle is attached to the scapula, or shoulder blade. From thence it runs down the arm and across the elbow joint to the radius bone of the forearm, to which it attaches with its lower end. Now, when this muscle contracts it tends to pull the bones to which it attaches toward each other. But the scapula is fixed and immovable. So the only bone which moves is the radius, which is bent up on the elbow joint toward the scapula, and the arm and hand going with it, the whole forearm is bent (Experiment 1). On the back of the arm is another muscle, the triceps, which straightens the arm again.

These muscles often attach to the bones by long, strong cords known as *tendons* (Latin *tendo*, "I stretch"). You can feel at the wrist the tendons running from the muscles of the forearm to the fingers. They are closely packed here and bound down by a fibrous ring at the wrist. The big, rough ends of the long bones are for the attachment of these muscles or their tendons.

All muscles do not attach to bones. Some are in the walls of organs, like the heart or stomach, and by contracting make the cavities of these organs smaller.

Antagonistic muscles. The muscles are often arranged in sets—one set to pull a bone or a part one way, and another set to pull it back. Thus, on the front of the arm are muscles to bend the fingers, on the back muscles to straighten them again. In the face there are muscles at each side of the mouth, keeping it in shape. If one side of the face be paralyzed the pulling ceases on that side, while the other set of muscles has it all its own way, and distorts the mouth.

Each muscle is in reality a little engine. It is made up of organic substance, and contains, as we have explained in Chap-



Flexors and extensors of hand.

A, front of arm: 3, biceps; 3′, biceps tendon; 4, brachialis anticus; 5, triceps: all of upper arm. 7, flexor carpi radialis; 8, palmaris longus; 9, flexor carpi ulnaris; 13, flexor sublimis digitorum; 14, flexor longus pollicis; 15, flexor profundus digitorum; 16, palmaris brevis; 17, abductor pollicis: all flexors of hand and fingers, bending them to the arm. 6, pronator radii teres.

B, back of arm: 12, extensor carpi radialis longior; 13, extensor carpi radialis brevior; 14, extensor communis digitorum; 15, extensor carpi ulnaris; between 14 and 15, extensor minimi digiti; 18, 19, extensors internodii pollicis. All straighten hand and fingers.

ter II., under metabolism, a certain amount of energy stored up in this substance. When the muscle engine works, some of this organic substance is burned, and its energy liberated. Thus, by the burning of its fuel the muscle gets energy to produce its movements, just as the engine does from the burning of coal.[1]

The action of a muscle is controlled from the nerve centers. When we desire to make a certain movement, a message is sent from the brain along a nerve to the muscle which performs this movement. This message sets the muscle engine going, just as an electric current sent by pushing a button starts a bell ringing or a machine running.

I. THE MECHANISM OF MOTION

The movements of the body by muscular action are performed for the most part through the mechanism of the lever system.

The *lever* (Latin *levare*, "to lift") is a contrivance to gain either greater power or greater range of motion. By pressing your weight upon the long arm of a lever you can raise several times, say twice or thrice, this weight upon the other end, thus gaining power. By moving the short arm of a lever one foot you may move an object upon the other end a longer distance, say six feet, thus gaining range of motion.

The mechanism consists of a bar, the *lever*, resting upon a fixed point, the *fulcrum*. If the fulcrum is in the center of the bar no advantage is gained either way. Thus, upon a tilt or seesaw, with equal parts of the board two people of equal weight will just balance each other. If one starts the tilt by a jump, the other will fall just the distance that the first rises. If one person is lighter, he is given more board, which

[1] When the muscles are in active use much more burning occurs, and more heat is produced in the body. Each of us can prove this by experience.

enables him to raise the heavier person by his less weight; but in doing it he has to ride over more distance than the other man on the short end. So, while the man on the long end moves a greater with a less weight, the man on the shorter end moves the long end a greater distance by going a less.

It is for this second purpose, the gain in range of motion, that the lever system is utilized principally in the body. The muscles occupy the place of the heavier person on the shorter end of the board. They attach to the short end of the bone which is placed as a lever, and by moving this a short distance move the other end of the bone, and all attached to it, a long distance. The muscles are strong enough for all practical purposes, and do not need to gain power. What they do need to gain is range of motion, so that the hand can reach about the body, or the legs take a long stride, and, by their extra strength applied to the lever, they can, by moving themselves one inch, move the end of a limb one foot or more.

THREE CLASSES OF LEVERS.

Levers are divided into three classes, according to the position of the fulcrum.

In Class I. the fulcrum lies between the weight and the power. A lever of this class is seen in the mechanism of moving the head forward and back. Here the fulcrum is the atlas upon which the head rests, the power arm is the small part of the head behind the line of the spine, the distance arm the front of the head and face. The power is applied to the short arm by muscles stretching from the spine to the head.

In Class II. the fulcrum is at one end with the weight between it and the power. When we raise ourselves upon our toes we use this form of leverage. The front of the foot is the fulcrum, the power is exerted upon the heel by

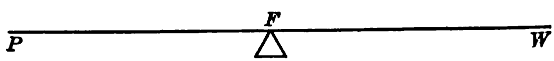
the calf muscles, the weight of the body rests between and is raised. In this leverage we lose distance and gain power.

In Class III. the fulcrum is at one end, with the power between it and the weight.

An application of this form of leverage can be seen in the flexing of the forearm.

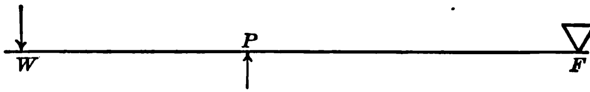
The forearm articulates with the humerus at the elbow. The biceps muscle starts from the scapula above, crosses the elbow joint, and attaches by its tendon to the radius of the forearm just below the joint.

When the biceps contracts or shortens it pulls upon the forearm, which is bent upon its hinge joint, and the free end of the arm comes toward the shoulder. The fulcrum is the



Lever of Class I.

Lever of Class II.



Lever of Class III.

joint, the weight or distance arm the forearm and hand; the power is applied by the muscle near the fulcrum. By moving a short distance the part of the bone to which it attaches, by its contraction through an inch or so the biceps moves the hand on the end of the long weight arm a foot.

The extension of the forearm is accomplished by the triceps muscle through a leverage of Class I.

The flexion of the hip is an application of leverage of the third class, similar to the flexion of the forearm.

Walking. The movements of the body are thus accomplished by the mechanical arrangement of muscle, bone, and joint.

In walking, one leg and foot is carried forward by the muscles which bend the thigh upon the hip. At the same time the knee is slightly bent by the muscles which flex it, to take the toes from the ground. This foot is placed on the ground before the other foot has left it. The body is then raised on the toes of the posterior foot, chiefly by the action of the calf muscles pulling on the heel, and given a push forward by the toes as they leave the ground. This hind foot is then swung forward in turn and grounded in time to catch the forward weight of the body.[1]

One side of the body tends to outwalk the other. This, if not corrected, would lead us to walk in a circle, as people frequently do who are lost in the woods.

In moderate walking very little muscular effort is used, as the legs swing forward after the first lift, like pendulums, of their own weight. The body is simply kept falling forward.

In vigorous walking more muscular motion is brought into play.

Running. In running, the legs are lifted and the body thrust forward by quick, vigorous action of the calf muscles and the extensors of the knee.

The upright posture. The body is maintained in the erect standing posture by the tension of the ligaments of the frame and the coöperation of certain muscles. With the feet as a support, the flexor and extensor muscles of the ankle both contract, and thus hold the ankle from bending and the

[1] In walking, the body oscillates from side to side, so that a man is never so tall when walking as when standing still.

leg steady in the midline. The knee is kept stiff by the contraction of the extensors, which prevent flexion, and the ligaments of the joint, which prohibit overextension.

The trunk is balanced in the midline, and is held there by the strong ligaments and muscles which pass from the pelvis to the thigh in front, and by the muscles behind. The head is held upright and in line by ligaments and by the contraction of the muscles of the neck.

If any change from the line is made by one part of the body, another part must be placed out of line in the opposite direction to adjust the balance. Thus, we may offset the tendency to fall in leaning forward by throwing the hips back or by putting a foot forward.

The postures of the body are thus regulated and controlled by muscular action. A man who has lost his power to control his muscles through nerve disease or through poisoning by alcohol reels in his gait and falls frequently.

II. THE ORGANS OF MOTION—THE MUSCLES—CLASSES OF MUSCLES

Voluntary and involuntary muscles. Muscles in the body are of two kinds, voluntary and involuntary.

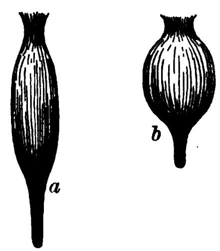
The voluntary (Latin *voluntas*, "the will") muscles are under control of the will. All the muscles which produce motion of the parts of the skeleton, as in walking, bending, grasping, talking, chewing, are voluntary.

The involuntary muscles (Latin *in*, "not," and *voluntas*, "will") lie principally in the walls of organs and vessels, and by their contractions produce movements of these walls. Thus, the food is forced through the stomach and intestines by the action of the muscles in the walls of these structures. They are controlled by unconscious nervous action, and perform whether we will or not.

The voluntary muscles are, as stated, attached by one end to a fixed body. This attachment is called the *origin*. At the other end they are attached to a movable body. This attachment is called the *insertion* (Latin *inserere*, "to implant").

Among the voluntary muscles which appear prominently upon the surface of the body are the *biceps* of the arm, the *deltoid* of the shoulder, the *pectoralis major* (Latin *pectus*, "chest," and *major*, "greater") of the chest, the flexors and extensors of the forearm, and the calf muscles of the leg. The *biceps* (Latin *bis*, "twice," and *caput*, "head"—two-headed) flexes or bends the forearm. You can feel this muscle harden, and see it grow shorter and bulge out, as you bend your arm. You can feel the several muscles upon the front of the forearm stiffen and stand out when you close the fingers, and feel them soften, and the muscles on the back of the arm stiffen and stand out like cords, when you open the hand widely. The *calf* is made up of two muscles which are very strong, as they have to be to lift the whole body. They attach to the heel by a strong tendon, the *tendon of Achilles*. (See list, with plate, pp. 76–78.)

Structure of voluntary muscle (Experiments 6–8). A muscle is a soft, tough mass of tissue, having, as a rule, a thick red central portion, with one or both ends tapering into white cords, known as *tendons*. Its appearance can be judged by looking at the beef in the market stalls.



Striate muscle.

a, at rest (relaxed); *b*, contracted.

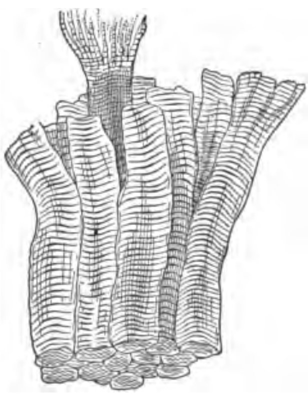
Some muscles have a tendon at one end only, some no tendons, attaching directly by their *fasciæ* (Latin *fascis*, "a bundle") to the bones.

The tissue of voluntary muscles is known as *striate muscle* tissue. Each muscle mass consists of a number of bundles of fibers, called *fasciculi* (Latin

diminutive of *fascis*, "a small bundle"), all bound together by a connective tissue sheath. Each fasciculus is surrounded and separated from the rest by a connective tissue sheath extending from the main sheath.

Each fasciculus consists of a bundle of muscle *fibers* running longitudinally.

Each fiber is enveloped in a sheath called a *sarcolemma* (Greek *sarx*, "flesh," and *lemma*, "husk"). The fiber consists of a semifluid substance which, as it lies in the sarcolemma,



Section of voluntary muscle, fibers separated.

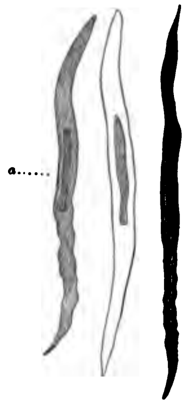
Voluntary (striate) muscle fiber.

has a striate (striped) appearance, showing alternate dark and light bands running across it. Each fiber represents a cell and has a nucleus. It can be teased (separated) into fine threads, or *fibrillæ* (small fibers).

In contraction of the muscle each fiber grows shorter and thicker, thus increasing the breadth and lessening the length of the whole muscle.

The prolongations of the muscle, fasciculi, and fiber sheaths form the tendons, which are thus tough connective tissue structures. In the sheaths run blood vessels and nerves.

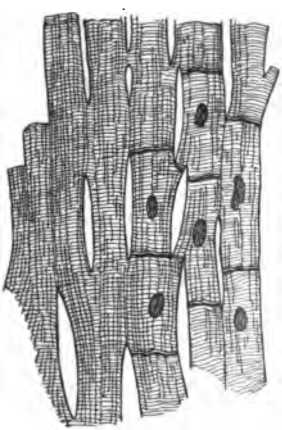
Structure of involuntary muscle. The tissue of most involuntary muscles is called *nonstriate* or plain muscle tissue. This tissue consists, like the striate, of bundles of fibers bound together by connective tissue. The fibers, however, are not striped and have no sarcolemma. They consist of elongated cells attached to one another. The fibers interlace.



Fibers of involuntary muscle.
a, nucleus.

The *muscle of the heart* differs in structure from both the above forms of muscle. It consists of fibers striated like the voluntary muscle, but, like the plain muscle tissue, having no sarcolemma and interlacing with one another.

In *chemical composition* the muscle contains a proteid substance, mineral salts, glycogen, and water. This proteid clots after death, causing a stiffness of the muscular system, known as *rigor mortis.*



Heart muscle.

In its action, as we have stated, the muscle burns up a portion of its substance.[1] This substance lost by burning and wear and tear of action its cells renew from the food which comes to it from the blood, so that during rest after a hard day's work the muscles are all built up again and made ready for more labor.

Corresponding to the several parts of the bony skeleton, the trunk, the limbs, etc., we have sep-

[1] The tissue burned is principally the carbohydrate store.

arate groups of muscles which regulate the motions of each of these parts or form part of their muscular frame.

The important muscles of each division, most of which can be seen in the plate on page 77, are as follows:

MUSCLES OF THE TRUNK.
(*Numbers refer to plate.*)

	Erector spinæ	moves the trunk backward.
30	External oblique Internal oblique	move the trunk forward.
17	Rectus abdominis	compresses the abdominal viscera.
	Intercostals	raise and depress the ribs.
	Serratus magnus	raises the thorax.
14	Trapezius Rhomboideus	move head backward; move shoulders backward.
16	Latissimus dorsi	draws arms downward and backward.
15	Pectoralis major (chest muscle)	draws arms across front of chest.

MUSCLES OF THE HEAD.

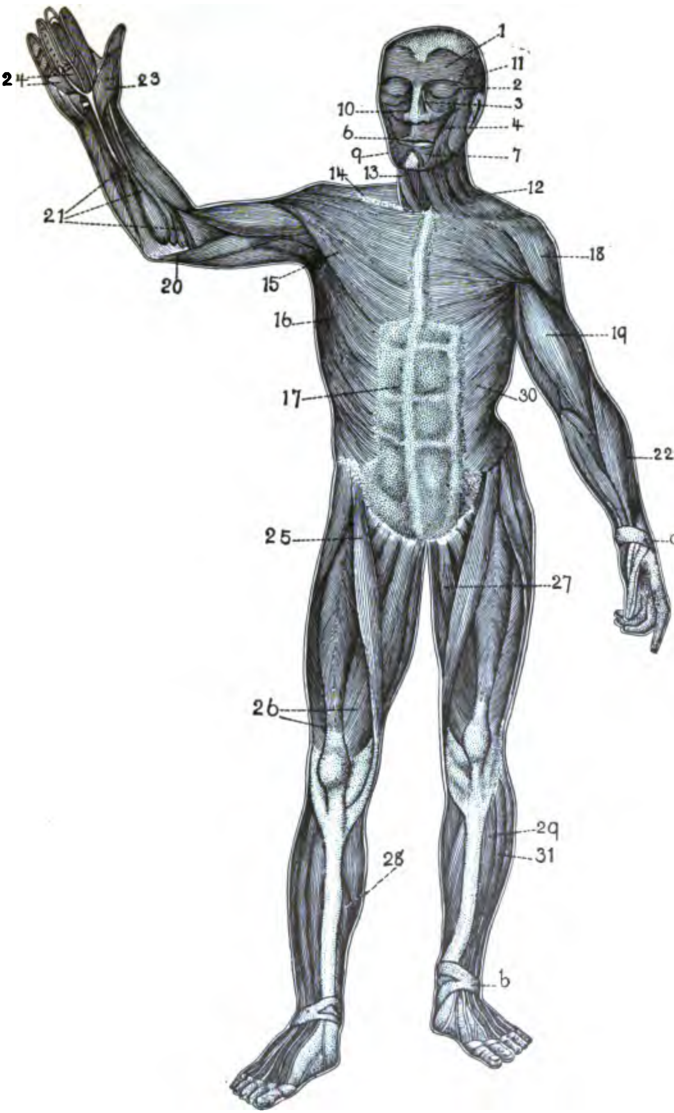
1	Occipito-frontalis	moves the scalp and eyebrows.
2	Orbicularis palpebræ	closes the eye.
	Levator palpebræ	opens the eye.
11	Temporal	raises the lower jaw.
9	Masseter	raises the lower jaw.

FACE MUSCLES.

7	Depressor labii inferioris	depresses the lower lip.
6	Orbicularis oris	draws lips together.
10	Compressor nares	depresses end of nose and draws sides together.
4	Zygomaticus major	draws angle of mouth upward and outward.
3	Levator labii superioris alæque nasi	raises the upper lip and side of the nose.

MUSCLES OF THE NECK.

12	Platysma myoides	depresses lower jaw and lower lip.
13	Sterno-cleido-mastoid	depresses head upon neck and chest.
	Scalenus	moves head and neck to the side.



The muscular system.

MUSCLES OF THE UPPER LIMB.

18	Deltoid (from shoulder to arm)	carries arm outward and upward.
19	Biceps	flexes forearm and raises arm.
20	Triceps	extends forearm.
	Brachialis anticus	flexes forearm.
22	Supinator longus	rotates and flexes forearm.
	Pronator radii teres	rotates forearm.
21	Flexor carpi radialis, Palmaris longus, Flexor carpi ulnaris	flex hand at wrist.
	Extensor carpi radialis, Extensor carpi ulnaris	extend the hand.

MUSCLES OF THE HAND.

24	Interosseous muscles	move fingers.
23	Abductor pollicis	draws thumb outward.
	Flexor brevis pollicis	flexes thumb.

MUSCLES OF THE LOWER LIMB.

	Psoas magnus (from trunk to thigh)	flexes thigh (moves it forward) on body, or body on thigh.
26	Quadriceps extensor cruris	extends leg at knee.
25	Sartorius	flexes lower limb and erects it; has been supposed to be the muscle chiefly concerned in producing the crosslegged posture of the tailor—hence its name.
27	Adductor longus, Adductor magnus, Gracilis	adduct thigh—move it toward other limb.
	Gluteus maximus	extends thigh at hip.
	Biceps flexor cruris, Semimembranosus, Semitendinosus (ham-string muscles)	flex leg at knee.
	Gluteus medius, Gluteus minimus	abduct thigh—move it away from other limb.
29	Tibialis anticus	draws up foot.
31	Extensor longus digitorum pedis	draws up foot and extends toes.
28	Gastrocnemius, Soleus (calf muscles)	raise body from ground upon the foot; raise heel.

Hygiene of the muscles. The development of the muscles depends upon a proper supply of food, exercise, and removal of the waste formed by this exercise or muscular work.

Use of food. As we have said, the wear of the muscle tissue involved in muscular work has to be made up by new food brought to the muscle. A man who works hard needs more food than one who rests, as he is using up more tissue.

Use of exercise. To develop strong muscles, however, it is not enough to eat plenty of food. The food must be driven to the muscles. This assimilation of more food by the muscles, and their consequent development, is accomplished by *exercise.* If a man eats a large amount of food and does no work he will simply get fat or ill. If he exercises, some of the extra food will go to form muscle, and his muscles will become large and strong.

A good amount of exercise is almost as necessary to a man's health as a proper amount of food or of sleep. It makes him stronger in muscle, heart, and lungs. It increases the activity of the circulation, and thus helps to distribute the blood well over the body and to carry away the waste products which collect in the body from the combustion of the tissues, which if allowed to remain cause loss of force.

Every one wishes to grow up as strong and able as possible. To do this he must know what things are good for him to eat and what things are bad, what exercise to take, and how to take it.

He must choose good, nutritious food, like milk and meat and eggs and bread and vegetables and fruit, and not take in their stead pastry and sweets, which are not so useful, and which disorder his digestion.

He must avoid especially all substances which may weaken and unfit him for work, such as alcohol and tobacco.

Effect of alcohol upon muscular work. Alcohol, when taken into the body as in its ordinary use as a beverage, lessens the

body's power for muscular work. This fact has been demonstrated by experiments upon large armies of men.

In the British army in Africa, for instance, the experiment was tried of testing how far the soldiers could march when taking daily what were considered moderate amounts of rum, and then how far they could march when taking no liquor, and comparing the records. So also in the Army of the Potomac, in the American Civil War, the same experiment was tried with whisky.[1] When the records are compared it is found that soldiers can endure longer marches when taking no liquor than when allowed their daily portion. These and other experiments of the same nature thus demonstrate that alcohol has the effect of diminishing the capacity of a man for muscular work, even when the alcohol is taken in what are generally considered as moderate amounts.[2] From these results we are justified in concluding that the

[1] The sirdar, Sir Herbert Kitchener, and General Gatacre, in their advances up the Nile, have strictly forbidden the supply of alcoholic liquors to any of the troops under their command. We learn that they took this step on two grounds. First, on the ground that from long experience they were convinced that the physical condition of the troops would, under these conditions, be enormously improved, and the men would have much greater staying power, while their dash, determination, and steadiness would also be increased. The second ground appears to have been that the mental and moral stamina of the troops would be preserved in a far greater degree than could possibly be the case if alcohol were served out. The result has been that the health, spirits, and conduct of the troops have been the admiration of all those who have had any dealings with them, and this experiment on a large scale has been an unqualified success.—J. Sims Woodhead, M.D., Professor of Pathology in the University of Cambridge, England.

See also Parkes (Proc. Royal Soc., No. 150, 1874) on the issue of the spirit ration in the Ashanti campaign.

Hall, Kaffir War, 1855–56.

Baer, Centralbl. f. allgem. Gesundheitspflege (1886).

[2] These experiments do not controvert the accepted fact that energy may be derived from alcohol in the body. They show that, owing to some effect of the alcohol, the body cannot get a sum total of benefit in the form of muscular work from this energy of the alcohol. There are experiments which show that men may do an increased amount of work for a very short time under the influence of alcohol; but such increase is accomplished, experiments as the above show, only at the expense of energy or tissue which is needed for bearing sustained labor or exposure. Thus, in some experiments upon British regiments, the regiment which had liquor took the lead at the start, but was far behind at the finish.

drinking of alcoholic liquors, even in so-called moderation, is a bad practice for any one who wishes to do hard work or endure sustained exertion.

This knowledge is a direct contradiction to the common idea that a glass of liquor increases the power to work. If the poor man were aware of this harmful effect of liquor, it would keep him in many instances from spending for a glass of beer or ale or whisky the money which should be spent for strength giving foods, such as bread or meat.

In skill and accuracy, and in the direction and expenditure of energy, the man who has taken no alcohol has a great advantage over the man who has. He is more calm in an emergency, and can judge better how to make his strength most effective. This effect of alcohol was remarkably demonstrated in the naval battle off Santiago, in the recent Spanish-American War, in the incapacity of marksmanship shown by the Spanish gunners, who were given alcoholic drinks under the false idea that it would "fortify" them for their work.[1]

Exercise. Exercise should be regular and judicious. If taken to the point of fatigue day after day it does harm.

[1] The attention of the civilized world has been called to the conspicuous fact of the accuracy of the firing of the gunners on our battle ships in the recent war with Spain. The contrast between the firing of the men of our navy and that of Spain was due in part, no doubt, to the custom that prevails on the ships of the latter, where daily rations of grog are given at all times, and when an action is going on or anticipated, double rations of grog are furnished to the men, while since 1862, when that custom was abolished by our government, no rations of liquor are allowed at any time on board our ships.

The custom just alluded to as followed by Spain is true of all the navies of the world but ours. Yet Great Britain has abandoned the double rations of grog when a fight is on, and then no liquor is allowed, but in place of it supplies of water and oatmeal are arranged all over the ship to satisfy the thirst resulting from the heat, exertion, and smoke inseparable from a naval combat.—The Journal of the Amer. Med. Assoc., January, 1899, p. 174.

It is said that a desire to excel in athletic sport has led clubs of students at some of the German universities to give up their "morning drinking bout." They have learned that beer drinking stands in the way of their best physical development and the highest degree of athletic success. "For years sports have been in great favor. Some of these, such as contests between boatmen or between cyclists, require considerable energy and power of endurance. Evidently if alcohol increased strength

One should not feel used up, but like taking more exercise, when one stops.[1] During exercise more blood flows to the muscles than during rest. Exercise should not, therefore, be taken soon after meals, as the blood is needed at that time for the digestive organs.

Training. People who exercise regularly establish a habit of the system whereby the flow of the food to the muscles, its assimilation there, and the oxidation of the muscular tissue, are accomplished at least cost to the organism. Such people are said to be in *training*.

Even development. Every one in training the muscular system should guard against developing these organs at the expense of the vital organs, the heart, lungs, and nervous system. Large muscles are of little use without a strong heart to keep them nourished. The man who can lift a great dumb-bell is not so useful as the man who can lift less but can endure muscular strain longer. The *real strength* is in endurance of work and exposure, and resistance to disease. This is found in an evenly developed organism.

Exercise should be chosen to develop the muscles throughout the body. Running develops the muscles of the legs rowing with a sliding seat the arms, back, and legs. Horseback riding develops the legs and trunk. Swimming and wrestling are very excellent exercises. All vigorous exercise develops the muscles of respiration and the heart.

If any group of muscles is undeveloped, special exercises should be practiced to develop these, as chest-weight pulling,

these competitors would provide themselves with it and use it freely. But this is not the case. No true sportsman, either before or during the contest, touches a glass of spirits, experience having taught the harm he would thereby do to himself." (Dr. Bienfait of Liége.)

[1] One cause of fatigue is the accumulation of the waste products of the combustion of the tissues involved in muscular exercise. In excessive exercise these may collect in the blood more rapidly than they are eliminated by the lungs, kidneys, and other excretory organs. In such cases they act as a poison, inhibiting (preventing) the output of nerve or muscular energy, and the fatigue that we feel when this occurs is nature's warning to cease exercise until the waste products are eliminated.

dumb-bell and club swinging. As a rule out-of-door exercises, which are carried on as a pleasure rather than as a task, should be utilized as much as possible, and supplemented, if necessary, by some systematic gymnasium work.[1]

Rest: The periods of rest should be as regular as those of exercise. In these periods, especially during sleep, the muscles renew the tissue which they have used up during exercise.

Clothing. The clothing which is worn should be loose, so as not to restrict muscular action. It should not be too thick, or it will restrict the escape of the extra heat generated by the exercise.

Care in bathing the skin must be observed, for an unclean skin hinders the excretion of the waste substances caused by the combustion of the muscles in action, and any accumulation of such waste products poisons the system and lessens the power of action.

Muscular exercise is good not only for the health of the muscles, but for that of the whole body. A man can use his mind with more efficiency, has a better circulation and a better digestion, if he exercises regularly. The action of the muscles increases the circulation all over the body, and thus increases the elimination of waste products, whether produced by brain activity, muscle activity, or digestive activity. The heaviness and inaptitude for work which are common to people who do not take enough muscular exercise are due to

[1] Walking is good exercise, but the amount of benefit to be derived from walking depends on the way it is practiced. A slow walk over smooth pavements for a well person is not to be compared with a tramp through woods, over rough fields, or climbing hills. Really graceful walking is something of a fine art, and is comparatively rare. To walk well one should take a free and firm but light stride, balancing the upper part of the body alternately on each hip, but without swaying it perceptibly, and giving the impetus forward with a light spring from the ball of the foot.

Bicycling has become one of the most popular forms of exercise. It is well suited to people in sedentary occupations and to women. The cyclist, however, takes more exercise than he is aware of, or than he intends, and is particularly liable to overtax his strength. Riding to reach a given point laid down in plans for the day, or to keep up with a club, or to finish a hill when very tired, but near the top, are the bicycler's temptations, but they should be resisted, or harm may result.

the sluggishness of the circulation and the accumulation of waste substances, conditions which disappear with regular exercise. Children and adults who devote all their time to study or brain work, and neglect their exercise, will suffer for it. There is a time for all things. The most useful man is one who has a strong brain, strong muscles, and a strong heart. The object of muscular exercise is not to develop modern Samsons. Bodily vigor should be cultivated, not as an end, but as a means to an end. Intellectual and spiritual perfection are the real ends. The body is but the instrument. A flabby state of the muscles keeps the body on the verge of a breakdown, and therefore a poor instrument.

Tobacco smoking or chewing diminishes the usefulness of the muscles, first, by hindering their development if practiced during youth; second, by its poisonous action whenever practiced. The paralyzing effect of tobacco upon the nerve centers diminishes the amount of nervous energy which a man can use in moving his muscles. All smokers are familiar with the inertia for muscular effort which comes after smoking. Tremor of the hand is also common with smokers when they try to perform acts requiring steadiness.

DEMONSTRATIONS AND EXPERIMENTS

1. Place the fingers in the hollow of the elbow, and as the forearm is flexed, note the tendon of the biceps muscle which draws up the forearm.

Note that the belly of the muscle swells and becomes hard in action.

Measure the circumference of the arm over the biceps, first while the arm hangs free, second when the forearm is strongly flexed. Note the difference.

2. Find upon the skeleton the marks of the origin of this muscle upon the scapula; also the mark of the insertion of the tendon upon the radius.

3. Note in the front of the wrist the prominent tendons of the forearm muscles which flex the hand.

Holding the hand extended, flex the fingers, and note the motion of the deep muscles and tendons beneath the skin of the forearm.

4. Note upon the back of the hand the tendons of the extensor muscles of the fingers and hand.

5. To note how the muscles and tendons act as ligaments supporting the bones in the joints, clinch the fist and see how the cords upon the back of the hand and wrist tighten, as well as those upon the front.

6. Structure of muscle.

Examine a piece of lean beef shank. Note the fascia which holds the bundles.

Boil thoroughly. Pick the fibers apart. This will show that muscle is made up of many fine fibers bound together, and will give some idea of its structure.

7. Get a turkey leg. Note the white cordlike tendon in the back of it. Pull this tendon and see how it moves the foot, just as did the muscle which pulled this tendon during life.

8. If some of the very finest muscle particles of the beef (Experiment 6) are placed in a drop of water, or, better still, a drop of one per cent solution of common salt, the striped (striate) character of the fibers can be made out under the microscope (two hundred diameters).

9. Structure of a joint.

Get a joint of a fowl with the two bones.

Note how the muscles and tendons cross it from the bone above to the bone below.

Note the action of these muscles and the joint.

Note the ligaments which hold the bones together at the joint.

Cut through the capsule of the joint.

Note the smooth surfaces of the bone, lined with cartilage and moist with synovial fluid, and how they glide one upon the other.

10. Study the action of joints.

To illustrate the combined action of muscles and joints in regard to mechanism and force, the school should be provided with a "joint apparatus." A description of such an apparatus and the experiments which may be made with this apparatus will be found in the "Outlines of Requirements for Harvard."

11. Proportion of water and solids in muscle.

Cut up some fresh muscle. Weigh and dry it until the weight remains constant. Determine loss of weight.

12. Demonstration.

To a nerve muscle preparation from the hind leg of a dead frog attach a recording apparatus. Apply a single electrical shock to the muscle. Note result. Apply single shock to nerve. Note result.

Apply rapid succession of shocks to nerve. Note result.

QUESTIONS

I. What are the organs of motion? Where does the energy for this motion come from? How is it liberated? Describe a muscle. What is the characteristic property of muscle? Describe the method by which a muscle, as the biceps, accomplishes a motion of the part (the forearm). What are the rough places upon the ends of the bones for? What is meant by antagonistic muscles?

II. Where is the action of each muscle controlled? Upon what system is the physical mechanism of motion in the body based? Describe a lever. What are the objects of the utilization of a lever? For which purpose is it principally used in the body? Describe some motion of your body illustrating each of the three classes of lever. Describe the act of walking.

III. How is muscle classified according to its mode of action? Where are the muscles of each class found? Describe the structure of voluntary muscle. What are tendons? What is the tendon of Achilles? What is the origin of a muscle? The insertion? Describe the structure of involuntary muscle. What kind of muscle is heart muscle? What is rigor mortis?

IV. What is the chief requisite in regard to the food for purposes of muscular development? What practice besides the eating of sufficient amounts of food is necessary for the full development of muscle? What is the effect of the taking of alcoholic liquors during long periods upon the capacity for muscular work?

V. What kind of exercise is best? What muscle in the body is it most important to have strong and sound? What is the best time for exercise? How much exercise should be taken at a time?

VI. When a man wishes to move a heavy stone too large to lift, what instrument does he employ? What is the mechanical principle involved in the use of this tool? What is the principle used in attaching a horse to a pole running through a central axis, as in the moving of a house along a road? Give some illustrations of the utilization of this principle in the body. Can you move both the upper and the lower jaws?

CHAPTER V

THE NUTRITION OF THE BODY

I. FOOD. II. THE DIGESTIVE ORGANS. III. DIGESTION AND ABSORPTION. IV. CIRCULATION AND ASSIMILATION.

THE maintenance of life means the maintenance of activity of some kind. Man is constantly using his muscles in motion and locomotion. The brain is constantly active in directing these movements and in thinking. Even in sleep, the cells of the body are in constant activity regulating metabolism and the transformation of energy; the blood is being circulated by the heart action, the air is being breathed in and out.

Need of food. All this constant activity means the expenditure of much energy. As described in an earlier chapter, the energy for work is supplied in the body by the combustion of the tissues themselves. The stored-up "*latent* [Latin *latere*, "to lie hid"] energy" of tissue substance is converted to "*dynamic* [Greek *dunamis*, "force"] energy" for work and heat by the oxidation of the substances with the free oxygen breathed in through the lungs. The process entails a constant wasting, a burning up of tissue substances. This waste has to be provided for by a constant replacement of the decomposed substances with new substances of the same kind; that is, the tissues must grow as fast as they waste, otherwise the body would wear out and life would cease.

The material for the constant renewal of tissue the animal gets in his *food*. By the frequent taking in of a food supply, sufficient when burned in the body to produce as much energy as is used there and to repair the nitrogenous waste, the equilibrium of the organism is maintained.

I. THE FOOD

Constituents of animal food. The tissues are made up of combinations of certain elements. As stated on page 21, these are principally carbon, nitrogen, oxygen, hydrogen, sulphur, sodium, potassium, calcium, chlorine, phosphorus, iron, and magnesium.

Since these elements are the constituents of the tissues, they must be the constituents of the food which is to renew the tissues.

Need of organic foods. The body is unable to take up in their pure or separate state some of these constituents which it needs for the building up of its tissues. Thus, it cannot take up the element nitrogen from the air, in which this substance exists in its free state, and it cannot use pure carbon (charcoal) as a food.

To use these substances the body has to get them in previously prepared combinations with hydrogen and oxygen. Some of these combinations, known as organic foods, can be taken up by the body and broken up within it; and the nitrogen and carbon which are contained in them can then be used by the tissues as they are liberated by this breaking up of the organic substances.

So while the body takes some elements and some food substances in the simple form in which they exist in the air and soil, as free oxygen from the air, hydrogen and oxygen in water, sodium and chlorine in salt, the greater quantity of the necessary food substances is taken in the form of com-

binations, similar in character to those which exist in the body, that is, in the form of organic substances.

Thus, most of our foods we take as compounds of carbon, hydrogen, and oxygen, known as carbohydrates and fats, or of carbon, hydrogen, oxygen, and nitrogen, known as proteids. These compounds are built up from the elements in the air and soil by the plants, and we get them in vegetables and fruits, or in flesh, milk, or eggs, from the bodies of other animals which have eaten the plants. They are called *organic foods*.[1] In taking them we get not only the use of the nitrogen, carbon, and other elements contained in them for repair of our tissue, but also, as stated on page 27, the use of the energy which is stored up in them in their production by the labor of the plants. This energy of the foods is liberated for work in the body when the food is combined with the tissues and burned. This combination and this combustion, as we have seen, are carried on continuously by the tissue cells.

Classes of foods. The organic foods, as stated, are of three classes—*proteids*, *carbohydrates*, and *fats*.

Proteids (Greek *protos*, "first"—most important) are substances consisting of carbon, hydrogen, oxygen, nitrogen, and sulphur. The chief proteids of food are the gluten of flour and many vegetables, the albumin of eggs, the casein of milk, the myosin of meat. Proteid elements are the essential constituent of the body tissues. As they alone of the organic food substances contain nitrogen, they are absolutely essential in the food supply. As they also contain the other important constituent elements of the body, carbon, hydrogen, and oxygen, man can subsist upon proteid food alone, with the addition of water and mineral salts (Experiment 5, p. 122).

Carbohydrates are compounds of carbon, hydrogen, and oxygen. The chief carbohydrates of food are the starch of

[1] See definition of organic substances, page 20; also Experiment 4, page 122.

flour, rice, potatoes, cereals, the sugars of fruit, cane sugar, glycogen, cellulose of grains (Experiments 7 and 8, p. 123).

Fats are compounds of carbon, hydrogen, and oxygen.[1]

The chief fats of food are butter and cream from milk, fat of meat, oils.

Both carbohydrates and fats enter into the formation of the body tissues. Neither food is absolutely essential to the renewal of tissue, however, as either can be built from proteids. As these foods contain no nitrogen, the tissues cannot be sustained upon them alone. They are of great use for the acquirement and production of energy in the body, as they contain much latent energy and are easily broken up to liberate it.

In addition to the organic foods man must have water and minerals. *Water* he gets in most foods (Experiment 10, p. 123). Thus, many vegetables contain eighty per cent of water in their substance. In addition man does and should drink a certain amount of extra water.

The *mineral salts* he gets from his organic foods (Experiment 11, p. 123). Thus, the sodium chloride, phosphates and carbonates of calcium, magnesium, iron, and so forth, are contained in the milk and meat and grains and vegetables. One salt, the chloride of sodium, he takes separately as common salt.

Quantity and proportion of foods in diet. A man must take as much food as he uses up. A man who works needs more than a man who stays in bed or one who loafs. In doing more work he uses more energy, and the production of this energy entails greater waste of his tissue, which has to be replaced.

A man with moderate exercise uses up in a day about four thousand grains of carbon and about three hundred grains

[1] In *carbohydrates* the hydrogen and oxygen are combined in the same proportion as in water, i.e., two of hydrogen to one of oxygen; in the *fats* the hydrogen and oxygen are not combined in the same proportion as in water (Experiment 9, p. 123).

of nitrogen. This is the amount which comes away as waste, the carbon in carbon dioxide, the nitrogen in urea, and this is therefore the amount which must go into his food. If he takes more carbon or nitrogen than he needs it will do him no good, but simply make more work for his organs.

Choice of food. So in choosing his food he must try to get a combination which contains these amounts of carbon and nitrogen, but not much more of either. To do this he has to make his meals of several kinds of food, as most foods do not contain in the right proportions all the substances which we need. Thus, bread contains both carbon and nitrogen, but in such proportions that a man has to take twice the necessary amount of carbon to get the necessary nitrogen. A man would need four pounds of bread a day to subsist on bread, which, besides giving him the extra carbon to dispose of, would necessitate his eating a large bulk of food and overtaxing his digestion.

Meat alone, to give the necessary amount of carbon, would contain three times the amount of nitrogen required.

If, however, a man combines bread and meat, or meat and vegetables, he can get the proper amount of the necessary elements into his body without marked excess of any kind. That is the reason that men live on a *mixed diet.*[1]

There are some foods, as milk, which contain the carbon and nitrogen in proper proportion; but in taking enough milk to supply the body an adult has to take an excessive quantity, and gets more mineral salts and fat than he needs. The growing infant needs these salts and fat, and thus thrives on milk.

Certain vegetables, beans or peas for example, contain nitrogen and carbon in about the proper proportions.

[1] The Eskimo lives upon animal food alone, the Hindoo upon vegetable food; but experience teaches us that the peoples of the world who have accomplished most are those who use both kinds of food.

II. THE ORGANS OF DIGESTION AND ABSORPTION

How the food gets to the tissues. We have seen that the material necessary for the production of the body tissues, and of the energy to keep the life going, is supplied to the cells by the *ingestion* (Latin *in*, "in," and *gerere*, "to carry") of food. In order that this food which we eat may be of use to the organism, it has first to be digested (Latin *dis*, "apart," and *gerere*, "to carry"), then absorbed (Latin *ab*, "from," and *sorbere*, "to suck up") and carried to the cells, where it is assimilated (Latin *ad*, "to," and *similis*, "like"—to make like).

The food is first taken into the alimentary canal, consisting of the mouth, stomach, and intestines. Through the walls of this canal it is absorbed into the blood, and carried by this to the lymph, from which the cells take it up.[1]

Object of digestion. The food, like all substances, is made up of a combination of minute particles, called molecules. The walls of the alimentary canal may be likened to a very fine sieve. Through this sieve the molecules of the food must pass before they get to the blood. Now, the molecules of most of our food substances are too large to go through the sieve; so the food substances have to be changed in the canal to other substances with smaller molecules before they can be absorbed. This process of the transformation of the food into soluble, diffusible materials is called *digestion*.[2]

[1] It must be understood that the real utilization of the food is in the cells of the various tissues. The digestion and circulation, and the organs which accomplish these functions, are useful merely to prepare the food for the cells, and to get it to them. All higher animals have organs of this kind, because the cells are so placed that the food has to be brought to them. In very low forms of animal life (as the amœba), however, there is no digestive or circulatory system. The cell takes up the food directly from the water or earth about it, wherever it comes in contact with any food, just as the cells in our body take the food up from the blood or lymph.

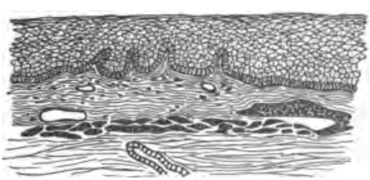
[2] Thus, the proteid substances of meat and bread, the albumins and so-called native proteids, will not pass the membrane of the intestine into the blood. They have first to be digested to peptones, which will pass through these animal membranes.

The process of digestion and absorption is really far more complex than this description implies. The intestinal walls are not a true sieve. The absorption is due to the activity of the living cells, which pass the substances through them. But the food first does have to be broken into smaller molecules to get through the cells, and thus the process is analogous to the straining through a sieve (Experiments 15, *a*, *b*, 16, 17, pp. 125–127).

The alimentary tract. Digestion of the food takes place, as we have said, in the organ or series of organs known as the alimentary (Latin *alere*, "to nourish") tract or canal.

This canal, starting with the *mouth*, includes the structures known as the *pharynx*, *esophagus*, *stomach*, and *intestines*. Connected with it are several structures known as *glands*, which assist in its function, as the *salivary glands* (Greek *sialon*, "spittle"), *liver*, and *pancreas*. The whole combined structure of canal and glands forms one great digestive organ.

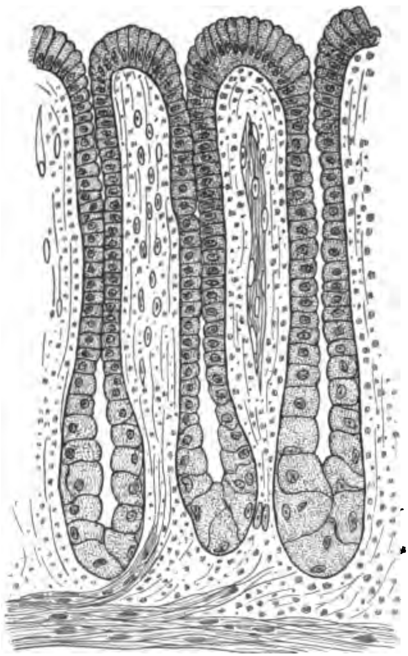
The mucous membrane. The whole alimentary canal is lined with one continuous membrane, known as the mucous membrane. This membrane is lined with an inner layer of epithelial cells of cubical or cylindrical shape, which secrete a fluid substance known as *mucus*. Besides the epithelial layer or layers, the membrane consists of an under layer of connective tissue carrying nerves and vessels. The walls of the canal include this mucous membrane, and in most parts outside layers of plain muscular tissue, which give them motion. The stomach has three muscular layers, the intestines two layers.



Mucous membrane.

Glands. Throughout the whole length of the canal are structures called glands; these manufacture substances

and pour them into the canal to aid in digestion and absorption. These glands may lie in the mucous membrane of the canal, as the gastric glands, or form separate isolated structures, as the liver.



Glands in mucous membrane.

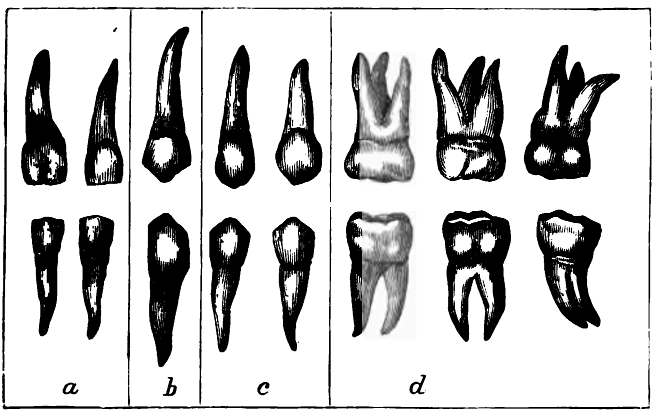
In structure, a gland consists of a collection of epithelial cells built up in connective tissue around a well or duct. The simplest gland is merely a blind tube lined with secreting cells. It looks like a well, the cells lying about the wall like the stones in the wall of a well. Many glands consist of clusters of these short blind tubes branching out from one another, all built up by connective tissue into a separate structure with nerves and blood vessels. Such are the racemose (Latin *racemus*, "a bunch of grapes") glands, as the pancreas and salivary glands.

Secretion. The epithelial cells of the gland take up substances from the blood, and transform them into a new substance known as the gland secretion (Latin *secernere*, "to separate"). This they pour forth from their duct into the digestive canal. If we examine the secreting cells of glands like the salivary at a period when no digestion is going on in

the part of the canal supplied by these glands, we see that the protoplasm of the cells is filled with abundant granules. During digestion these granules disappear. They represent, together with the water and salts which are secreted by the cells, the material of the secretion.

The mouth. The process of digestion begins in the mouth. The mouth cavity contains the *teeth*, the *tongue*, the *palate*, and a digestive secretion, the *saliva*.

The *teeth* are hard, bonelike structures attached to the jaws. Each tooth consists of a *crown* and *fangs*. In its



Teeth.

a, incisors; *b*, canine; *c*, bicuspids; *d*, molars.

center is a cavity filled with soft pulp. The substance of the teeth is known as *dentine*. The crown, which is the part uncovered, is capped with a very hard substance known as *enamel*. Over the fangs, which are imbedded in the gums, is a substance known as *cement*, which cements the fang to the periosteum of the jawbone in the fang socket. Nerves and blood vessels enter the tooth by a central canal to the pulp cavity.

The two sets of teeth. Man has two sets of teeth—one the *milk teeth*, coming in infancy, a second the *permanent teeth*, replacing these in adult life. The adult has thirty-two teeth, sixteen in each jaw, and eight in each half of the jaw. In each jaw the four middle teeth are chisel-shaped for cutting the food; they are called the *incisors* (Latin *incidere*, "to cut"). Next to these on each side comes a pointed tooth, the *canine* (Latin *canis*, "dog"—like a dog tooth); then two *bicuspids* (Latin *bis*, "twice," and *cuspis*, "spear"— two-pronged) on each side, with double crowns and forked fangs; last, three *molars* (Latin *mola*, "mill"), or grinders, which have large, rough crowns for crushing the food, and several fangs.

The milk teeth are twenty in number—two incisors, one canine, and two molars on a side of each jaw. They come during the second year, and drop out to make way for the permanent set in the sixth or seventh year.

The *tongue* is a movable muscular organ covered with a mucous membrane. In this membrane are situated the organs of the sense of taste. In health the surface of the tongue is red and moist.

The digestive secretion of the mouth, the *saliva*, is a viscid, watery, alkaline fluid. It is poured into the mouth from the orifices of the ducts of three pairs of glands, the *parotid* (Greek *para*, "near," and *ous*, "ear"), the *submaxillary* (Latin *sub*, "under," and *maxilla*, "jaw"), and the *sublingual* (Latin *sub*, "under," and *lingua*, "tongue") glands, situated in the tissues of the throat and neck. The parotids, just below and in front of the ears, are the glands which are swollen in the mumps.

Mastication (Latin *masticare*, "to chew"). The work of the mouth in digestion is principally a mechanical one. By movements of the lower jaw the food is broken up between the teeth. This is called mastication. The food by the same process is thoroughly mixed with the saliva and softened. This food is then collected by the action of the tongue and

cheeks and thrust into the back of the mouth. By the contraction of the muscular walls of the fauces, the bolus, or ball (Greek *bolos*, "a mass"), of food is then squeezed into the pharynx, the soft palate, or uvula, a tissue curtain which

Dissection of face, showing parotid gland with duct leading to the cavity of the mouth, and submaxillary gland.
p, parotid; *sm*, submaxillary; *d*, duct of parotid; *n*, nerves (branches of facial); *f*, artery of the face.

you can see hanging from the roof of the mouth at its posterior end, being raised.

The *pharynx* is a cavity connecting the mouth with the esophagus. The *uvula* (Latin *uva*, "grape") shuts it off from the mouth. Above it is entered by the posterior openings of

the nose cavities, at the sides by the Eustachian tubes connecting with the middle ear, in front below by the larynx, behind by the esophagus. The *epiglottis* (Greek *epi*, "upon," and *glottis*, "glottis") is a fold of tissue which extends from the walls of the larynx across the opening from the pharynx to the larynx, and shuts off the larynx and windpipe from the pharynx while food is passing. When not perfectly closed the food may get into the windpipe. This is what occurs when food "goes the wrong way."

Deglutition (or **swallowing**) (Latin *deglutire*, "to swallow"). The food is carried through the pharynx by the continuation of the muscular action of swallowing begun at the fauces, and is forced into the esophagus. It is then forced along the esophagus by the action of the muscular walls, and into the stomach. The first part of swallowing, the forcing of the food through the fauces, is voluntary. After the food reaches the opening of the esophagus the swallowing goes on without our conscious control.

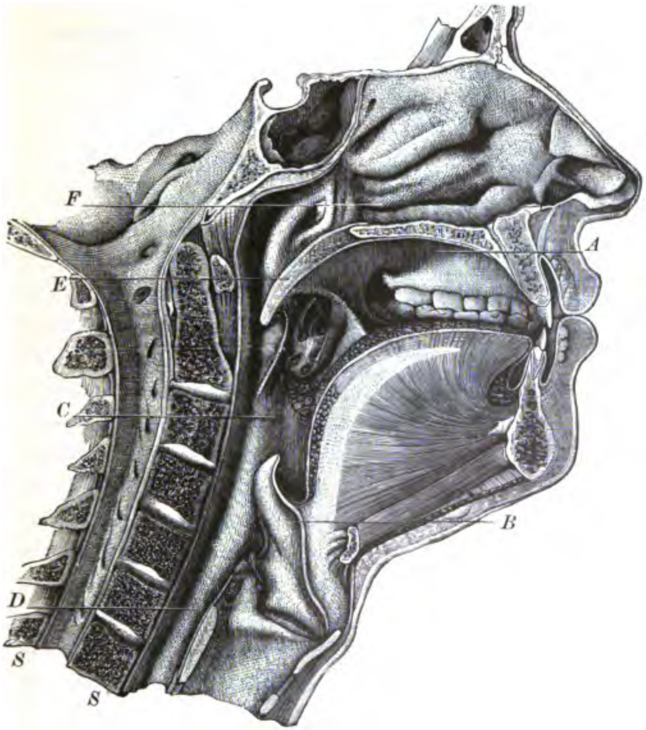
The *esophagus* (Greek *oiso*, "I shall bear," and *phagein*, "to eat") is a muscular tube which runs along the spine from throat to stomach. Its walls contain striate and plain muscular tissue, which aids in the progress of the food.

The *stomach* is a dilated pouch of the alimentary canal lying in the upper part of the abdomen, and rests just below the ribs on the left side. In structure its walls consist of a mucous membrane and three layers of muscular tissue about it.

The *mucous membrane of the stomach* is lined with a single layer of cylindrical epithelial cells. Throughout the surface of the membrane are numerous shallow pits, into which open the ducts of the gastric glands which lie imbedded in the membrane. (See diagram, p. 94.)

The principal secretion of the stomach is a watery acid fluid known as the gastric juice.

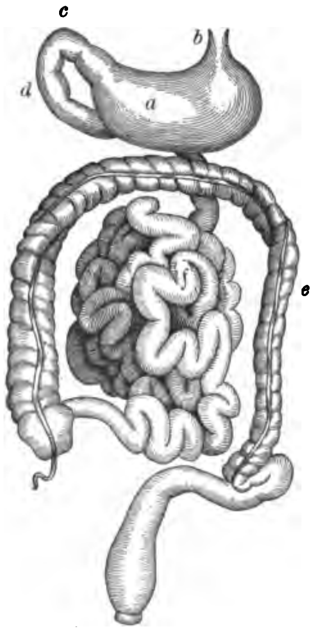
The food enters the stomach by the opening from the esophagus, the *cardiac* (Greek *kardia*, "heart"). Here it is thoroughly mixed with the secretions by the motions of the stomach walls, and digested. It is then pushed, by the mus-



Section showing course of food through pharynx and esophagus.
A, cavity of mouth showing teeth; *B*, epiglottis; *C*, pharynx; *D*, esophagus; *E*, soft palate; *F*, nasal cavity; *S*, *S*, spine.

cular action of the stomach walls, through the passage from the stomach to the intestines, the *pylorus* (Greek *pule*, "gate," and *ouros*, "keeper"). This pylorus is an opening bounded by a firm muscular ring. During digestion in the stomach

the opening is closed most of the time by the contraction of the muscle. From time to time it relaxes and allows a little digested food to pass through. When all the food is digested as far as it can be in the stomach, the whole mass passes into the intestine.



Stomach and intestine.[1]
a, stomach; *b*, cardiac orifice; *c*, pylorus; *d*, duodenum; *e*, large intestine; *f*, small intestine.

The *intestine* (Latin *intus*, "within") is divided into the *small* intestine and the *large* intestine. It consists of a tube twenty-five feet in length, lying mostly in coils in the abdomen, below the liver and stomach. The coils are supported by folds of connective tissue known as the *mesentery* (Greek *mesos*, "middle," and *enteron*, "intestine"), which carry blood vessels to the intestines. Externally both the stomach and the greater part of the intestine are covered with the serous covering of the abdominal cavity, the *peritoneum* (Greek *peri*, "around," and *teino*, "I stretch").

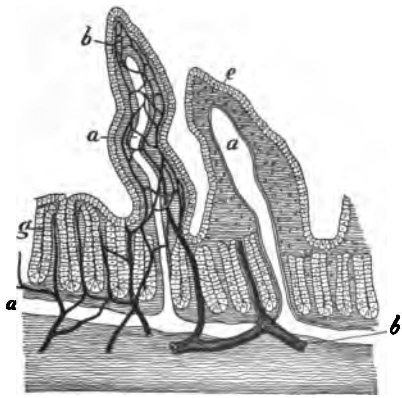
The walls of the intestine consist of a mucous membrane and two layers of muscular tissue external to this.

In the small intestine the mucous membrane lies like a loose sleeve in folds or tucks called *valvulæ conniventes*. The membrane is filled with numerous small glands, the *crypts of Lieberkühn*, which open among the cells of the lining epithelium. Between the glands the membrane is raised into many

[1] This cut is diagrammatic and does not give exact positions or relations of the organs included.

small processes called *villi*, which give to the surface of the intestine the appearance of velvet.

The *villi* (Latin *villus*, "a nap of cloth") are organs for the absorption of the digested food. Each villus is a minute pillar or conical elevation made up of connective tissue lined with the epithelial cells of the intestinal membrane, and carrying blood vessels and a lymphatic vessel known as a *lacteal* (Latin *lac*, "milk"). The food is passed through the cells of the villus wall, collected in the lacteal and efferent vessels, and borne away to the blood stream. The intestinal wall also contains collections of glands called Peyer's patches.



Villi in mucous membrane of small intestine.

a, lacteal; *b*, blood vessel (vein); *e*, epithelial cells; *g*, glands.

Besides the secretions from the crypts of Lieberkühn and other glands which lie in the wall, the intestine is also supplied by secretions from two large glands which lie separate from it and empty into it by ducts, the *liver* and the *pancreas* (Greek *pan*, "all," and *kreas*, "flesh").

The *liver* is a large gland which lies beneath the diaphragm (the large muscle which forms the floor of the thoracic cavity and the roof of the abdominal cavity) and ribs, mostly on the right side of the abdomen. A secretion of this gland, the *bile*, is poured into the intestine during digestion. It aids in the digestion and absorption of the food, principally the fats. From the blood which is brought to the liver by its

afferent vessels, the hepatic artery and portal vein, substances are taken up by the liver cells and formed into certain products known as bile and glycogen. The substances are taken from the blood on one side of the cells, combined, and the compound formed is discharged as bile into ducts on the other side of the cells. These ducts finally bring the bile to a large duct, the *hepatic duct*, which runs into the intestine.

Connected with the bile duct is a large bladder, the *gall bladder*. The bile is secreted continuously. During digestion it is poured into the intestine. At other periods it is stored in the gall bladder, from which it is discharged when digestion is on again. The bile is, in part at least, an excretion in which waste is removed from the blood. It is useful in part also as a secretion facilitating the digestion and absorption of fats in the intestine.

The *pancreas* is a gland lying in the bend of the small intestine. It consists of clusters of blind tubes lined with cubical cells, all uniting in a large duct which enters the intestine.

The partly digested mass of food from the stomach, the *chyme*, enters the upper intestine through the narrow constriction of the stomach, the pylorus, which relaxes to allow it to pass. Here it is mixed with the intestinal secretions, such as the bile and the pancreatic juice, and further digested. As the now well-digested food is forced along by the contraction of the muscular walls of the intestine, much of it is absorbed by the villi and intestinal cells. The residue is forced along into the large intestine.

The *large intestine* is separated from the small by a valve, the *ileocœcal valve*. Just beyond this valve lies the pouch called the appendix. This appendix is a rudimentary structure corresponding to a useful one in the lower animals.

The wall of the large intestine, like the wall of the small

intestine, consists of mucous membrane and muscle layers. The membrane is filled with tubular glands, but contains no villi.

The muscles of the walls are arranged in three longitudinal bands. The contents of the small intestine, the food which has escaped absorption there, the indigestible residue, and the detritus from the intestinal walls and the blood, are passed along the large intestine. Here more food and most of the water are absorbed. The residue is passed on as a thick mass to the rectum, where it is expelled as *fæces* (Latin *faex*, "dregs").

HYGIENE OF THE ORGANS OF DIGESTION

The members of the body rebelled against the Belly, and said, "Why should we perpetually engage in ministering to your wants, while you do nothing but take your rest and enjoy yourself in luxury and self-indulgence?" The members carried out their resolve, and refused their assistance to the Belly. The whole body quickly became debilitated, and the hands, feet, mouth, and eyes, when too late, repented of their folly.—ÆSOP.

The action of the organs of digestion and absorption is regulated by what is known as an automatic ("self-acting") nervous mechanism, and is beyond our conscious control. We simply provide the proper food at the proper intervals, and the digestion goes on without our giving any thought to the process. In fact, beyond attending to the thorough mastication of the food and the swallowing of small amounts at a time, the less we think about the process of digestion the better.[1]

But although we do not control this function, we can, by

[1] The mind has a marked influence upon the process of digestion. Strong emotions, such as fear, anger, or grief, at mealtime destroy both the appetite and the power of digestion. Business cares and anxiety brought to the table counteract the best efforts of the best of cooks. All unpleasant topics or remarks should be accounted hygienic sins. Mealtime is the time for fun and laughter, for pleasant stories and amusing anecdotes.

care in diet and in the practice of eating, influence to a great extent the health of the organs and the efficacy of their function. We must eat plenty of food in order to provide for the body needs; but in so doing we should always choose and take the food in such a manner as to avoid injuring the digestive organs, and to make their work as easy as possible.

In the first place, we must have our food as digestible as possible. It is foolish to use up the energy of the organs and perhaps injure them by giving them some indigestible substance like green apples or tough meat, when we can get as much or more nourishment from some easily digestible food.[1]

Mastication. We can aid in the digestion of the food by chewing it thoroughly. Food which is broken up into fine particles and softened is more easily digested, as the digestive juices can get at it better. If we swallow large pieces of meat or bread they are very slowly digested, and thus burden and perhaps injure the stomach.

Care of the teeth. To chew our food thoroughly we must have good teeth. If the teeth are not properly cared for they decay, and thus we may lose them. If the food substances which collect about them in chewing are allowed to remain there, they undergo a process of fermentation or decomposition, and form substances which are injurious to the teeth. The teeth should be thoroughly brushed at least twice daily. Some harmless tooth powder recommended by a competent dentist, or a good soap, should be used as often as necessary to keep them free from tartar. The particles of food which collect between the teeth should be removed by some soft thread, as floss. Neglect of cleanliness, besides

[1] Some indigestible residue is useful (see p. 138). Thus, the residue of fruits and vegetables keeps the intestines in working order. But the above principle is to be followed in general.

facilitating decay, permits a substance known as tartar to collect upon the teeth, which helps to loosen and destroy them.

People with poor teeth frequently suffer from indigestion, as the food cannot be broken up into small pieces before being swallowed, or collects some of the foul decomposition products from the mouth, which irritate the stomach.[1]

Cooking. To make our food more digestible most of it is prepared by cooking. This process disintegrates and softens the food, so that we can more easily break it up in the mouth and stomach. Thus, the nutritious muscle fiber of meat is separated from its indigestible connective tissue supports. The hard shells of corn and oats are softened and separated.

Cooking also brings out the flavors of food substances and makes them more appetizing.

Eating too fast. The food should be chewed slowly and swallowed in small amounts, as the stomach can take care of the food better if it receives it a little at a time. There is no more common cause of indigestion than rapid eating.

Drinking. Large amounts of liquid should not be drunk with our meals, as this dilutes the digestive juice and delays digestion. A glassful of water may be sipped with the meals. An equal amount of water should be taken in the same manner between meals.

Overeating. We must be moderate in the quantity of food which we eat. Stuffing overloads and stretches the stomach,

[1] Forty newsboys, ranging in years from fifteen to eighteen, applied recently for appointments in the United States naval service. Thirty-eight out of the forty were rejected on account of physical defects, the cause of rejection in most cases being unsoundness of the teeth.

Savages have stronger teeth than civilized men, owing probably to the fact that they eat harder food, which exercises the muscles and blood vessels of these parts and keeps them well supplied with blood.

The teeth are especially liable to decay soon after their appearance; the enamel has not then attained its maximum density. They should be watched and a dentist consulted as soon as any signs of decay are detected.

so that it cannot do its work. It irritates the walls of the stomach and causes inflammation.

The body needs a certain amount of food daily. If we eat more than this we do not get stronger, as the body cannot use it. We simply overtax the digestive and eliminating organs. Overeating makes people dull and lazy. They cannot work well; they build up fat instead of muscle, and this fat is a burden, not a benefit, to them. They get their organs out of order and suffer from indigestion and biliousness.

Further, we must not eat large amounts of one substance, but should divide our diet among several kinds of food, as meat, vegetables, bread, milk, fish, fruit.

The habit of eating large amounts of sweets, as candy, cake, and pastry, is a bad one. The body does not need so much sugar. It cannot use it, and the organs get overworked and out of order. There is a very serious disease, known as *diabetes*, which sometimes is associated with eating much sweet food. This eating of sweet substances also takes away our appetite for other foods which are necessary.

The *amount of food* which we need varies with the work which we do and the climate in which we live. Men who work hard all day need more food than those who rest or loaf. In cold weather or in cold climates people need more food than in warm. The cold air tends to remove more heat from the body, and this loss has to be made up for by more food. The Eskimos, who live in the North, eat tremendous amounts of food, often as much as fifteen pounds a day.

Mealtime. Eating between meals. In order that we may not overburden the digestive organs we divide our food into meals. It is best in temperate zones to take three meals a day, at intervals of about five or six hours—say breakfast at seven, lunch or dinner from twelve to one, dinner or supper at six. Between these meals one should not eat, as the digestive organs, like the body itself, need some time to rest.

A man should not eat heartily within one or two hours of bedtime, as the function of digestion is less active during sleep.

He should not do hard work with his muscles or with his brain directly after a meal, as this exercise takes the blood away from the digestive organs, where it is needed.

When a man comes in tired, it is a bad plan for him to eat heartily at once. In his fatigued condition the functions of digestion will not respond to the call upon them.

Finally, we must avoid all substances which irritate or injure the digestive organs or disturb their function.

Relishes. The spices—pepper, curry, and similar substances—which are added to foods to make them appetizing are frequently irritating to the membrane of the stomach. The healthy man has a good appetite to make him relish his food, and needs no extra relishes. If, however, he gets used to having his food highly spiced, he becomes dependent upon these additions and the feeling of warmth which they cause in the stomach. He thus has to continue irritating his stomach and liver to keep up an appetite.

Alcohol. Prominent among these substances which may irritate and injure the digestive organs are the beverages known as alcoholic liquors. Alcohol is a distinct irritant of tissue. If it be applied to the tongue it causes a burning sensation. It does the same thing when it touches the mucous membrane of the stomach. This irritation, where it is often repeated or severe, causes disorder and injury of the stomach. The irritated cells pour forth an excessive secretion, and become in time, if the irritation is kept up, incapable of performing their ordinary function.[1]

[1] Chittenden (American Journal of the Medical Sciences, vol. cxi.; American Journal of Physiology, vol. 1.) has made careful experiments upon the effect of varying amounts of alcohol upon gastric digestion. He finds, in digestion experiments made with mixtures of digestive juice outside the body, that even small amounts of alcohol retard digestion. The same amounts cause a slight increase in the secretion of gastric juice when taken into the body. The retardation effects and the secretion effects practically neutralize each other, as regards the total effect of alcohol upon gastric digestion.

The harmful action of alcohol upon the digestive organs does not stop with the stomach. The liver, which purifies the blood flowing from the alimentary tract, has this irritant substance passing through its cells. Where this irritation is long continued there is reason to believe that the cells are injured: the liver becomes less able to perform its functions. Habitual drinkers not infrequently suffer from an incurable disease known as cirrhosis of the liver, of which the alcohol is in all probability to some extent a cause.

Another practice which is apt to injure the digestive organs is taking hot or cold substances. Very hot substances cause inflammation of the mucous membranes of the mouth, esophagus, and stomach.

Drinking much ice water without food irritates the stomach walls and makes one liable to indigestion. Drinking it with food often benumbs the cells, and thus delays the secretion of gastric juice and digestion. If one drinks ice water he should take simply a few sips at a time, as this small amount is warmed by the body almost as soon as it reaches the stomach.

The drinking of large amounts of liquid is apt to stretch the stomach and make it less able to perform its functions. Thus, beer drinkers often have stomachs which are stretched much beyond their natural size. Such stomachs cannot, as a rule, digest food or pass it on to the intestines for absorption so well as normal stomachs.

Tobacco. Smoking is very apt to set up an irritation of the stomach and a disordered state of the secretions. This is due in part to the large amounts of saliva and mucus swallowed, and in part to the systemic action of the poison. The tobacco often seems to relieve the desire for food. This it does by benumbing the nerve sensibility upon which the sensation of hunger depends. By such action it impairs the appetite.

Chewing gum. The habit of chewing gum as a rule is one to be avoided. This practice calls forth an excessive secretion of saliva. This saliva is swallowed, and either keeps the stomach in a constant state of excitation or hinders the activity of the acid juices there.

DEMONSTRATIONS AND EXPERIMENTS

A good object lesson in regard to the needs of mastication, and to the adaptation of the teeth and jaws for different kinds of food, may be obtained by the study of the method of mastication, and the teeth and jaws, of various animals.

A carnivorous (flesh-eating) animal, as the dog, seizes his meat and swallows it with but little chewing. A herbivorous (vegetable-feeding) animal, as the horse, chews his food for a long time, with a lateral as well as an up-and-down movement of the jaw. This suggests that vegetable foods are less easy to digest and need more breaking up and mixture with saliva than animal food; and this is true of uncooked vegetable food, oats, grass, etc. If you look at the jaw of the horse or cow you will see that its articulation allows of a lateral motion, while that of the dog allows only a hinge (up-and-down) motion. This is to enable the horse to grind his food thoroughly.

The teeth of the carnivora will be seen to be adapted for tearing and cutting, even the molars having sharp edges, and closing past each other like the blades of a pair of scissors.

The teeth of the herbivora will be seen to be fitted for grinding, the molars having rough, flat surfaces. These teeth, like an emery wheel, though they grind other things smooth, are themselves always rough. That is because they are formed of two substances, which wear away at different rates, so that an uneven surface is always left.

If we now examine our own teeth and jaws we shall see, first, that we have both the cutting teeth of the carnivora and the grinders of the herbivora; second, that our jaws allow of both the up-and-down and the lateral motion; so that we are fitted for both the animal and vegetable diet.

It is noticeable that among civilized nations the teeth are becoming less sound and vigorous. This is partly due to the fact that with the use of cooked food, food already ground and softened, there is less use

for the teeth, and so, according to the law of evolution, they, as superfluous organs, are tending to disappear.

MASTICATION AND DEGLUTITION

1. Chew and swallow slowly some food substance.

Note how the different teeth act in the mastication, how the tongue and cheek muscles help in the process.

Note that swallowing begins as a voluntary act, but that the food once started is beyond control.

2. Note where the skin ends on the lips and where the mucous membrane begins.

3. Wipe the tongue dry and place sugar upon it. At first there is no taste, as the sugar has to be dissolved to affect the taste organs.

4. Look into a boy's mouth and wipe the part under the tongue dry. As you look a drop of saliva will collect.

III. DIGESTION AND ABSORPTION

We have obtained an idea of the nature of the food with which the body must be supplied, and of the organs by which this food is digested and made ready for assimilation by the tissues. We must now endeavor to trace this food from its entrance into the alimentary canal to its destination where it appears transformed into tissues, muscle, flesh, and bones.

Salivary digestion (Experiment 13, p. 124). Digestion of the food begins in the mouth, under the action of the saliva. The saliva is an alkaline fluid which contains a ferment called *ptyalin* (Greek *ptualon*, "saliva"). This ptyalin has the power at the temperature of the body of converting starch, which cannot be absorbed through the membrane of the alimentary canal, into sugar which can be absorbed. Digestion of the starch of bread or vegetables therefore begins when such food has been mixed with the saliva.

You can illustrate this digestion by holding in the mouth a little starch paste (see Experiment 13, p. 124) and noting the sweet taste which develops in a short time.

The proteids and fats are not acted upon by the saliva.

Digestive ferments. These ferments, of which ptyalin is an example, are very important agents in digestion. They are chemical products of the gland cells which have the power of bringing about changes in the food substances without themselves being used up in the process.[1] There are other forms of ferments, of which the yeast cells and bacteria are examples, which are alive. They are called *organized* ferments. In distinction from these the chemical ferments are known as *unorganized ferments.*

Digestion in the stomach (Experiment 14, p. 125). The food enters the stomach as a soft mass mixed with the alkaline saliva. Here it is mixed with the digestive secretion of the stomach known as the *gastric juice* (Greek *gaster*, "stomach").

This juice secreted by the gastric glands upon the stimulation of the food contains an acid, hydrochloric acid, and two ferments, *pepsin* (Greek *peptein*, "to digest") and *rennin.* It acts principally upon proteids. The acid and pepsin acting together convert the native albumins of meat and vegetables to *albumoses* and *peptones*, forms of proteid which can be absorbed. The rennin coagulates casein, the proteid of milk.

The action of the saliva upon starch is stopped by the acid gastric juice. The carbohydrates and fats are not digested by the gastric juice, which does, however, digest away the albuminous envelope of the fat cells, and thus by freeing the fat facilitates its digestion later.

Digestion in the intestine. The food, after remaining in the stomach until proteid digestion is sufficiently advanced, is propelled into the intestine. This period is from three to six

[1] The most important digestive ferments are the ptyalin of the saliva and the amylopsin of the pancreatic juice, which convert starch to sugar; the pepsin of the gastric juice and the trypsin of the pancreatic juice, which convert albumins to albumoses and peptones; the rennin, which coagulates (curdles) milk; the ferment of the intestinal juice, which inverts cane sugar.

hours with a full meal. Practically but little absorption occurs in the stomach.

The digested gastric contents, or chyme, enters the duodenum, and is there acted upon by the pancreatic juice and bile and the secretions of the intestinal glands (see p. 128).

The *pancreatic juice* is a watery alkaline fluid containing sodium carbonate and three ferments, *amylopsin*, *trypsin*, and *steapsin*.

The *amylopsin* digests starch to sugar. The starch foods which have escaped the salivary action, or those which have not been completely converted to glucose, are here fully digested.

The *trypsin*, like the pepsin, digests proteids, but in an alkaline medium instead of an acid. The proteids which escape complete digestion in the stomach are finished here.

The *steapsin* acts upon the fats, splitting the natural fat into fatty acid and glycerin.

The *intestinal juice* from the small glands which lie in the walls of the membrane contains a ferment which inverts sugar; that is, it turns the cane sugar which we eat to *invert sugar*, a sugar with smaller molecules, more suited for absorption.

With the action of the intestinal secretions the digestion of the food is completed. The native food substances have been converted to soluble forms with molecules small enough to pass the intestinal cells, the proteids to albumoses and peptones, the carbohydrates to invert sugar and dextrose (glucose).

The fats have been brought into a finely divided state known as an emulsion, or broken up into fatty acids and formed into soap, in which forms they can be absorbed (Experiment 15, p. 125).

Absorption. The alimentary contents are thus prepared for absorption into the blood. This process occurs through the

medium of the epithelial cells and the villi of the intestinal mucous membrane. The molecules of these substances formed as a result of digestion are small enough to be passed through these intestinal cells. Thus, during and after digestion these sugars, peptones, and fat products, the mineral salts and water, are taken up by the cells and transferred to the blood and lymphatics. Some of the products are passed unchanged into the blood, others are elaborated into different substances by the cells through which they are passed; but the essential food principles, proteids, carbohydrates, and fats, with water and inorganic salts, all get into the blood in some form.[1]

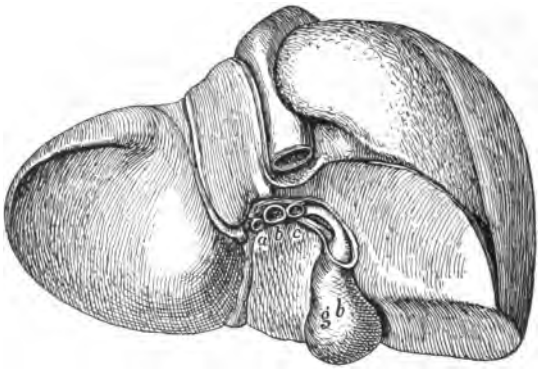
The villi in absorption. The structures described as villi are particularly active in this process of absorption. The epithelial cells of the villus pass the products through and discharge them into the blood vessels and the central lacteal. During digestion these vessels are loaded with these products, which they bear away to the blood. In this process the intestinal cells act like porters unloading a ship into railroad cars. The merchandise is taken from the ship (the intestine) and put upon the railroad (the blood vessels), which distributes it over the country (the body). After absorption the food is collected by two sets of vessels, the lymphatic vessels and the portal vein. The food collected by the lymphatics is called the *chyle*. It is collected together into a large vessel, the thoracic duct, and discharged from this into the blood.

The food collected by the blood vessels of the villi and the intestinal walls is discharged into a large vein, the *portal vein*. This vein carries it to the large gland already mentioned, the *liver*. Here it is, roughly speaking, filtered and further elaborated by the liver cells, its useful parts poured into the blood of the general circulation, while its harmful or poi-

[1] The physical processes involved in absorption are imbibition and osmosis, in all probability. Osmosis is described on page 120. See also page 126.

sonous elements are destroyed or turned aside into the bile for elimination from the system.

Structure of the liver. In structure the liver consists of cubical epithelial cells compactly arranged in bundles known as *lobules* (small lobes). Each lobule is built up with connec-



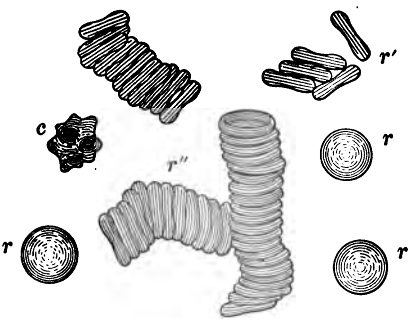
Liver.
a, *b*, *c*, artery, vein, and bile duct; *g b*, gall bladder.

tive tissue in which run numerous blood vessels from the portal vein. These vessels run between the cells in the center of the lobule. By these cells harmful substances or substances reserved for special purposes are taken from the portal blood. The purified food in the portal blood is then carried on to the blood stream which feeds the body tissues by the hepatic vein. The liver separates from this blood waste products which the blood has taken up in the body, as well as the waste food; for instance, the waste coloring matter of the blood corpuscles, and the waste nitrogen products which result from the breaking down of the proteid tissue substances. Some of these waste products are excreted in the bile. Others, as urea, are poured into the blood and excreted by the kidneys.

The liver cells also store up some of the carbohydrate food in the form of *glycogen.*

IV. CIRCULATION AND ASSIMILATION

The blood and lymph. The food which has been digested, absorbed, and purified has to be borne from the intestines and liver to the tissues which it is to nourish. Also, the tissues thus nourished have to be provided with free oxygen from the lungs for their combustion to form energy. Thirdly, the waste products of this combustion of the tissues have to be carried away and disposed of. This carrying of the food and waste of the body is the function of the *blood* and the *lymph*.



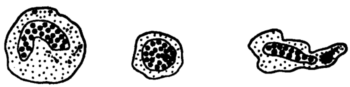
Red corpuscles.

r, corpuscle (full view); *r′*, corpuscles (side view); *r″*, corpuscles in rolls (rouleaux); *c*, crenated corpuscle.

The *blood* is a fluid substance of red color which circulates throughout the body. It consists of a watery substance, the *plasma*, in which are suspended great numbers of small semisolid bodies, the *corpuscles*. These corpuscles are of three kinds, the red corpuscles, the white corpuscles, and the blood plaques.

The *red corpuscles* are small circular biconcave disks, like coins, with their upper and lower surfaces hollowed out. The corpuscles give the red color to the blood. Each corpuscle has a diameter of from six to nine micromillimeters—about $\frac{1}{3200}$ of an inch. They are very numerous—about five million to one cubic millimeter of blood. If a drop of blood be spread upon a glass slide and looked at under the microscope, these corpuscles may be seen lying free or in rolls.

In structure the corpuscle consists of an elastic protoplasm, or stroma, in which is set the red coloring matter, ***hemoglobin***, much as the color is set in the glass of a colored marble. This hemoglobin is a very important substance which carries the oxygen from the lungs to the cells. In blood it is always combined with some of this oxygen, and is thus *oxyhemoglobin*.



White corpuscles.

The *white corpuscles*, or leucocytes (Greek *leukos*, "white," and *kutos*, "cell"), are colorless bodies of many sizes, but mostly larger than the red corpuscles. They are less numerous than the red, numbering about eight thousand to a cubic millimeter, or one to six hundred reds.

These *white corpuscles are really single cells*, which are free in the blood. In them we have a chance to observe the character of the living cell, which is the unit of structure in all the tissues.

Each corpuscle consists of a nucleus surrounded by protoplasm. The whole cell is enveloped in a cell membrane. The *nucleus* is more dense in substance than the protoplasm. Its form may be round or horseshoe shape or still more irregular. The *protoplasm* is a colorless, translucent substance. It is often filled with fine granules.

Like all cells at some period of their existence, these corpuscles are alive. They take up and discharge new substances to and from the plasma, divide and form new cells, and many of them have the power of amœboid motion (see p. 17). Owing to this power of motion they may take any shape, but as a rule they appear spherical in the blood.

The *blood plaques* are very small, protoplasmic, disk-shaped bodies.

Coagulation (Latin *coagulare*, "to curdle"). When the blood is taken from the body or exposed to the air for a few

minutes it forms a jellylike mass called a *clot*. This process of clot formation is known as coagulation. The coagulation is due to the formation of fine elastic threads in a thick network in the blood. This threadlike substance is called *fibrin*. In thus collecting it forms a firm mass which collects the corpuscles in its meshes. The fluid parts of the blood, the serum, may be squeezed out and separated.

Coagulation is a very useful process in stopping the bleeding from a wound by plugging up the opening in the vessels with the clot.

The fibrin is formed from substances in the plasma by the action of a ferment. The removal of this fibrin from the plasma leaves the serum (Experiments 20, 21, pp. 128, 129).

The *serum* (Latin for "whey"), which is the plasma of the blood minus the fibrin, consists of water with mineral salts, proteid substances, and certain other materials in solution. The proteids of the serum are two in number, *albumin* (Latin *albus*, "white") and *globulin*, substances like the proteid of white of egg (Experiment 23, p. 129).

The salts of blood are chiefly chlorides and carbonates of sodium and potassium and phosphates of magnesium and calcium. They are contained in both the plasma and the corpuscles. The corpuscles contain iron combined in the hemoglobin.

The food substances which are absorbed are carried in the blood in solution and in suspension. We thus have in the serum of blood after a meal proteid, carbohydrate, and fat substances which have been absorbed and are on the way to the tissues, also lime salts, phosphates, and other minerals going to the bones and brain and other tissues which need them.

The circulation of the blood. Thus, to carry the food and oxygen to the tissues and the waste away from them the blood is circulated through all parts of the body. This pro-

cess is called the *circulation* (Latin *circulare*, "to encompass") *of the blood.*

For the carrying out of this process an organ or series of organs is provided, the *circulatory system.* This system consists of the heart and the blood vessels.

The *heart* is a muscular pump which keeps the blood ever flowing.

The *blood vessels* are muscular and elastic tubes which conduct the blood over the body. Those which take the blood filled with food and oxygen to the tissues from the heart and lungs are called *arteries* (Greek *aer*, "air," and *terein*, "to keep." It was formerly thought that arteries carried air, as they were found empty of blood after death). Those which return the blood from the tissues with the waste materials are called the *veins* (Latin *venire*, "to proceed").

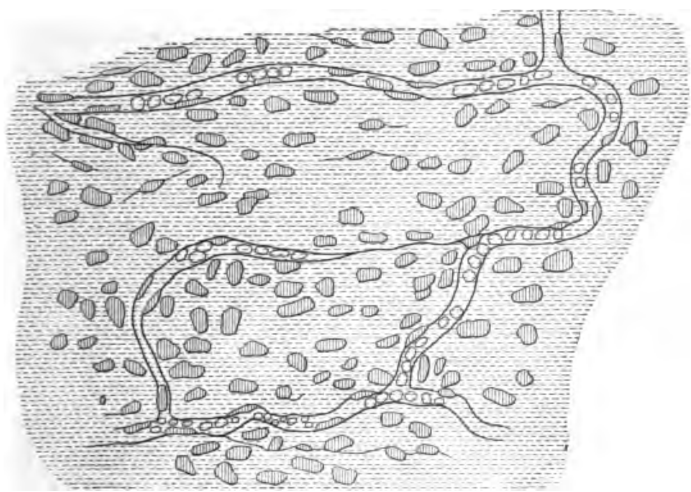
The arteries when they reach the tissue which they supply divide into fine tubes called *capillaries* (Latin *capillus*, "a hair"), which permeate the tissue and come together again in veins.

The food and oxygen in this arterial blood, during the passage of the blood through the capillaries, pass through the walls of the capillaries into the *lymph* (Latin *lympha*, "water"), which takes them to the cells. Some of the waste products from the tissues collected by this same lymph pass back through the capillary walls to the blood, just as in the experiment (p. 126) with the egg some of the water passes into the egg and some of the egg albumin into the water. The blood then goes on to the veins and through them, deprived of its food elements and filled with waste.

The veins bear this blood back to the heart, whence it is pumped to the excretory organs, as the kidneys, where it gets rid of the waste products, and to the lungs and alimentary tract, where it takes up a new supply of food and oxygen, and so on round the body again.

The blood which is going to the tissues filled with a supply of oxygen and food is called *arterial blood;* it is bright scarlet in color. That which is returning in the veins to the heart from the tissues is called *venous blood;* it is of a dark purple color.

This circulation of the blood can be studied in the web of a frog's foot. If we look at this web under the microscope



Blood in capillaries in tissue.

we see fine tubes dividing into still finer ones, all filled with blood. Through the larger tubes the blood comes flowing into the smaller. In the small tubes the flow is slow, the corpuscles going in single file. Collecting the blood from the fine capillary tubes, we see small veins of blue color.

The lymph. The blood flows in tubes, and thus does not get directly to the cells of the tissues, except the cells of the vessel walls. Its nutritious products are brought to the cells by what is known as the lymph.

The lymph is a watery liquid which fills the interstices of the tissue among the cells and about the capillaries.

The nutritious substances of the blood pass through the capillary walls into this lymph. The lymph gives them up to the cells which are bathed in it. At the same time the lymph collects the waste from the cells and returns it to the blood.

The process of interchange between the two fluids, the blood and the lymph, through a membrane which separates them, is called *osmosis* (Greek *osmos*, "impulse"). Where this process occurs we have two fluids of different densities separated by a membrane, as the intestinal mucous membrane, or the walls of a blood capillary; that is, we have, as in Experiment 16, page 126, on one side of the membrane a dense fluid, white of egg for instance, and on the other a thin fluid, water. When osmosis occurs these fluids interchange their substance, the dense fluid (the egg white) giving up its heavier constituent to the water, and the thin fluid (water) giving up its lighter constituent (the water itself) to the egg, so that they tend to become equally dense, the egg becoming watery and the water becoming heavier.

So in the circulation the blood gives up food substances, salts, and water; the lymph gives up waste substances. The same process is active in the absorption from the small intestine. Here the intestinal contents on one side of the membrane give up food to the blood on the other side and take up water from the blood, so that the intestinal contents become more liquid, while the blood becomes more concentrated.

The lymphatics. In this interchange between the blood and the lymph in the tissues the blood gives up a larger amount of fluid than it takes back. The amount of lymph in the tissues would tend therefore to increase all the time. This excess of lymph, however, is collected and carried away from the tissues by a set of vessels known as the lymphatics.

These vessels drain all the lymph spaces in the tissues. They collect into larger vessels and finally empty into the large veins, so that the lymph and its waste products all get back to the blood.

The lacteals, which collect some of the food absorbed from the intestine, belong to this system of lymphatics.

DEMONSTRATIONS AND EXPERIMENTS

1. **Reaction.** Acids and alkalis.

There are certain chemical substances which are known as acids. These substances can be tested for by using blue litmus paper. An acid or any substance which contains an acid turns blue litmus red. This test is the indication of the fact that a substance is an acid or contains an acid. The substance which gives this test is said to have an acid reaction. The gastric juice gives this test, as it contains hydrochloric acid.

Another set of chemical substances are known as alkalis. These substances turn red litmus paper blue, or yellow turmeric paper red. The saliva, the pancreatic juice, the blood, turn red litmus blue, as they are alkaline in reaction (contain alkalis).

Some substances do not change the color of litmus. They are neutral in reaction. Salt and water are such substances.

Test some blue litmus with hydrochloric acid; with sodic hydrate; with saliva. Test some red litmus with the same substances.

2. Solution.

When you add sugar or salt to water and shake the mixture, the solids disappear; the mixture remains clear. Such a mixture is known as a solution. The substances which thus disappear are said to be soluble in water. This process of solution occurs in the mouth, and stomach, and intestines. The sugar or salt eaten is dissolved there as in the test tube. Other substances, as starch and hard-boiled egg, are insoluble in water. They do not disappear in water or make a clear mixture. These substances have to be changed in the body (by digestion) to soluble substances.

Try shaking each of the above substances in water to illustrate the above statements.

3. Precipitates.

When two substances are mixed they may form a third substance.

Add some of a nitrate-of-silver solution to a solution of salt (sodium chloride). Note the formation of a third substance, a white powder which sinks in the liquid (chloride of silver).

This third substance is insoluble, while the first two substances were soluble. Such an insoluble substance formed by adding any chemical to a second chemical in solution is called a precipitate.

EXPERIMENTS UPON FOODS

A clearer understanding of the nature and composition of the various food substances will be achieved if the pupil familiarizes himself with the tests for the chief constituent substances of the foods—proteids, carbohydrates (starches and sugars), fats, mineral salts.

4. Demonstration of the adaptability of organic food for burning with charring.

One of the important characteristics of organic foods in distinction from inorganic is their adaptability for burning.

Place meat or any vegetable upon a hot fire. They will char and burn up. This is due to their organic (carbon-containing) character.

Place a rock or a lump of salt upon a fire. These will not char, as they contain no carbon, or burn, as they contain no substance which, like the carbon of organic foods, unites with the oxygen at the ordinary fire heat.

5. Tests for proteid substances.

A fairly pure proteid substance which is easy to experiment with is white of egg. Separate the whites of two or three eggs. Stir this egg albumin in a pint of water. Filter the mixture. With the fluid which has been filtered perform the following tests for proteids. These tests can be obtained upon the proteid substances of any food, as meat, corn, wheat, milk, etc.

(*a*) To a little of the solution in the test tube add some nitric acid. Note what occurs. Then add a little ammonia (ammonic hydrate) to the mixture. Note the color which appears. This is a test for proteid substances. (Xanthoproteic test).

(*b*) To some of the solution add some sodic hydrate and one or two drops of a one per cent solution of copper sulphate. Note the color which results. (Biuret test for proteid.)

(*c*) Heat some of the solution of egg albumin. The precipitate which appears is the albumin. (If no precipitate appears add one drop of dilute

acetic acid and heat again.) This is a test for a special kind of proteid, not all proteids.

6. How do these tests react upon meat juice?

7. Tests for carbohydrates. Starch.

(*a*) Rub up some corn starch with a little cold water. Add to this a gill of boiling-hot water. (This mixture is called starch paste.) To some of the milky mixture (cool) add a drop of tincture of iodine or of Lugol's solution. Note the color which appears. This test for starch may be applied to the starch of various foods, as potatoes, wheat, flour, fruit.

(*b*) Grate a potato into a glass of water. A white powdery substance which falls to the bottom of the glass is the starch of the potato.

8. Test for grape sugar (Fehling's test).

Dissolve a small amount of grape sugar in water.

Heat a small quantity of Fehling's solution in a test tube. To this hot liquid add an equal amount of the sugar solution. Note what occurs. Heat again. Note result, if any.

9. Tests for fats.

(*a*) Shake a small piece of butter (the fat from milk) or a little sweet oil (fat from olives) up with ether. What happens? Filter, and allow the ether to evaporate.

(*b*) Mix some ether with a tablespoonful of flaxseed meal. Let stand for fifteen minutes. Shake and filter, and allow ether to evaporate.

What is left in the evaporating dish in (*a*) and (*b*)? Add a little water to this residue. What do you observe?

Perform the same experiment with milk.

(*c*) Rub some flaxseed meal upon paper. Observe result.

10. To demonstrate the amount of water in foods.

(*a*) Weigh a piece of meat, as fresh beef. Set aside in a warm, dry place for twenty-four hours. Weigh again. The loss of weight is due principally to the water which has evaporated. Weigh at the end of forty-eight hours; seventy-two hours.

(*b*) Remove the peel from an apple or potato. Weigh the peeled fruit and allow it to dry. Note loss of water from day to day.

11. Tests for mineral substances in foods.

(*a*) Heat and fuse some flour or meat or milk in a crucible until heating causes no further change. The residue left (the ash) represents the mineral matter of the food, which, as you know, unlike the organic matter, does not burn.

(*b*) Dissolve some of the ash in water. Filter. To the filtrate (the watery solution) add some nitrate of silver. What appears?

Part of the precipitate which occurs is due to the salt, sodium chloride,

in the food, which, as in Experiment 3, page 122, forms, with the silver salt, the insoluble silver chloride.

12. Tests to show the constituents of milk.

(*a*) Allow milk to stand for some time. The thick layer which collects on the surface, the cream, consists principally of the fat which is contained in the milk.

(*b*) Test for proteid by general tests for proteids given on page 122.

Heat some milk and add some acetic acid. A thick, flocculent substance, known as curd, which consists of the proteid (casein) contained in milk, is formed. The whey is the liquid left after removal of the curd. If both the cream and the curd are removed from the milk it still contains a carbohydrate substance, lactose or milk sugar.

(*c*) If a little whey is boiled with Fehling's solution we get a yellowish-red substance. This red substance is due to the action of the sugar (milk sugar) in the milk upon the copper, and proves that sugar is present in the whey.

Shake some milk with ether, filter and evaporate. Note the fatty residue, which is the fat of the milk.

We can thus find and separate proteids, fats, and carbohydrate substances in milk.

Evaporate some milk by boiling. The loss in weight is due principally to the loss of water. The residue is the solid substance of milk. This experiment shows how great a part of milk is made up of water. Fuse the residue in a crucible. The ash or mineral constituents remain. Test the ash as in Experiment 11. Test for phosphates as in Experiment 7, page 62.

EXPERIMENTS TO ILLUSTRATE DIGESTION

13. Digestive action of saliva, illustrating digestion of starch.

(*a*) Place a little starch paste (Experiment 7, *a*, p. 123) on the tongue. In a short time a sweet taste will develop. This sweet taste is due to the sugar which is formed from the starch in the digestion by saliva.

(*b*) Add some starch to water. Note that the liquid mixture is cloudy. The starch does not disappear. Add some sugar to water and shake. Note that the sugar disappears. The liquid mixture is clear; that is, the sugar is more soluble in water than is starch. This shows one reason for the usefulness of the change of starch to sugar by digestion. This is not, however, the only reason. The fact that the grape sugar (glucose) molecule is smaller than that of the starch and can better pass through the intestinal membrane (absorb) is the chief reason.

(*c*) Chew some paraffin. Collect the saliva which flows in abundance into the mouth. Make some starch paste. Test with Fehling's test to prove no sugar is present. Add some of the saliva to some starch paste another portion of which has given the blue color with iodine. Put in a warm place (over a radiator). In five minutes perform Fehling's test. How did the sugar arrive? Twelve hours later perform the iodine test. The blue color will not appear, and a red color, or perhaps no change of color, will appear. The starch has all been turned to sugar or to other substances.

This experiment illustrates what occurs to starch in digestion in the body.

(*d*) Take some dry corn starch (uncooked starch) and mix with saliva. Test this mixture for sugar in five minutes. Is the effect of the saliva the same upon this uncooked starch as upon the cooked starch (the starch paste)?

The digestion of the starch in wheat, potato, fruits, etc., is carried on by the pancreatic juice in the same manner as by the saliva. The pancreatic juice, however, digests uncooked starch also.

14. Digestion by the gastric juice, illustrating digestion of proteids.

Mark two one-ounce bottles. Fill 1 with water; fill 2 with a mixture of hydrochloric acid and pepsin made up as follows: hydrochloric acid, 6 cc.; water, 1,000 cc.; pepsin, 10 gm. This represents an artificial gastric juice except for the absence of rennin.

Place a small piece of hard-boiled egg or fibrin in each bottle, and keep in a warm place, as over a steam radiator (not above the body heat).

Note that the egg remains unchanged in the first (water) bottle.

In the second it disappears, is digested. The digestion of proteids —the albumin of eggs, meats, grain, etc.—in the body occurs in this manner.

Here, as with the digestion of starch by saliva, the digestion often forms a soluble substance from an insoluble one. Witness the coagulated egg albumin in the above experiment. But the proteid substance is often soluble in the first place, in raw eggs, milk, etc., and the main object of the digestion is to break up non-absorbable proteids so that they will pass through the animal membranes.

Proteids are digested in the intestine by the pancreatic juice, as in the stomach by the gastric juice.

15. Digestion of fats.

(*a*) Place some butter in some water kept at the body heat (98.6° F.). What occurs? Shake up the water and fat, or some olive oil and water.

Do they mix? Place under the microscope a drop of the water which has been thus shaken. Can you distinguish the fat globules?

(*b*) Shake up some olive oil with a solution of sodic hydrate. Does any mixture of the substances occur?

Look at a drop of this mixture under the microscope. Can you distinguish the fat globules here as in the water?

The mixture of the fat and the alkali forms an emulsion. The two substances do not tend to separate after shaking, as in the case of the oil and water. The fat in an emulsion is so finely divided that you cannot see the globules.

(*c*) Mix some olive oil and sodic hydrate, and boil. Describe the mixture which forms. This is soap.

The processes illustrate in a rough way the digestion of fats in the body. The fat is melted in the stomach. In the intestine it is broken up and forms an emulsion with the alkaline fluids there, the pancreatic juice, bile, etc., some of the fat here being formed into soap.

(*d*) Obtain some bile. Test the reaction. Add some oil to bile and shake. Is an emulsion formed? Examine mixture under microscope.

EXPERIMENTS TO ILLUSTRATE ABSORPTION

16. Absorption by osmosis can be represented by the following experiment:

Make a hole about half an inch in diameter in the large end of an egg by breaking through the shell and cutting the outer shell membrane. The air space between the inner and outer shell membranes is thus opened. Then immerse the egg in a glass of water, with the open end upward and the lower end held in place by a ring support (a napkin ring). The albumin of the egg white is thus separated from the water by the inner shell membrane. Through this membrane osmosis occurs readily, the water passing inward and the albumin outward, so that the density of the egg contents and that of the water outside tend to approach each other. The water goes in, however, more rapidly than the albumin comes out, and as a result the membrane becomes more distended, bulges out through the hole, and finally bursts. This bulging demonstrates that the water is going through the membrane.[1]

Obtain some sacs made from animal membranes. (The sausage covers made from pigs' intestine are good for this purpose.)

Into a small sac made of the sausage skin pour a solution of grape

[1] This and several other experiments are taken from Dr. H. P. Bowditch's Hints for Teachers of Physiology.

sugar. Suspend the sac in a two-ounce beaker of distilled water. After a few hours test the water in the beaker for grape sugar. (Fehling's test.)

Perform the same experiment with a mixture of starch and water in the sac. Test water in beaker for starch. (Iodine test.)

Note that the sugar passes through the membrane, the starch does not. Starch therefore has to be digested to sugar to absorb.

Perform the same experiment with a solution of egg albumin. Test water for proteids. Perform the experiment with a solution of salt (sodium chloride). Test water for salt by adding nitrate of silver.

These experiments represent in a rough way one part of the process of absorption. The sausage skin represents the intestinal membrane. The sugar, the salt, etc., pass through this into the water, as in the body they pass through into the blood.

In the body, however, the cells of the membrane are alive and transform these substances as they pass through. In this dead membrane osmosis is the only active force present.

17. Physical methods of absorption.

Absorption occurs partly as a physical process, diffusion, but partly by a specific action of the living cells. The physical processes can be illustrated by the following experiments:

(*a*) Place a few pieces of glass tubing of different sizes in a glass of water, and note that the water rises higher in the tubes than in the glass, and highest in the small tubes. This represents the process of capillary imbibition, which is a part of the process of absorption in the intestine. The same thing can be illustrated by placing a piece of filter paper in water colored with aniline blue.

(*b*) The process of perspiration is an example of imbibition.

18. Fill out the following table with the results obtained by applying these common tests which have been described for proteids, carbohydrates, and fats to the food substances given.

Test.	Starch.	Grape Sugar.	Olive Oil (Fat).	Egg Albumin.	Peptone.	Meat Juice.
Heat						
Xanthoproteic						
Biuret						
Iodine						
Fehling's						
Solubility in ether						

DIGESTION BY THE PANCREATIC JUICE, ILLUSTRATING INTESTINAL DIGESTION

19. Procure a fresh pancreas from a pig. Cut up finely and grind with some fine sand in a mortar.

To one ounce of the pancreas add four ounces of twenty-five per cent alcohol, and let the mixture stand three days. Filter, and use the filtrate for experiments.

(*a*) Digestion of proteids by the pancreatic ferment (trypsin). To 10 cc. of the pancreatic extract add twice that amount of one half per cent sodium carbonate in a test tube.[1]

Into the tube place a small piece of coagulated white of egg or a piece of fibrin, and place mixture over a register or in any place where the temperature is about the body heat (98.6° to 100° F.). Note the gradual digestion of the proteid, which will, in time, disappear entirely.

(*b*) Digestion of carbohydrates by the amylolytic ferment of the pancreas. To 10 cc. of starch paste add an equal amount of one half per cent sodium carbonate, and then a few drops of the pancreatic extract, and warm the mixture. Note that the milky starch mixture becomes clear.

This pancreatic ferment digests uncooked starch also, which the salivary ferment does not do.

(*c*) Digestion of fats by the fat-splitting ferment of the pancreas. Carefully neutralize or make slightly alkaline a little of the pancreatic extract with the one half per cent solution of sodium carbonate. Add this mixture to 2 cc. of neutral olive oil to which a little blue litmus powder has been added, and stir the mixture.

Set in warm place. Note the change in the blue color of the mixture to purple and pink, also later the formation of an emulsion. (The red color is due to the acid which is formed by the action of the ferment on the fat.

EXPERIMENTS UPON THE BLOOD

20. Obtain a half pint of fresh blood from the slaughter house. Allow it to stand in a wide-mouthed eight-ounce bottle. After a time a cup-shaped clot will form, adhering to the glass. Below it will be the nearly colorless serum.

[1] The pancreatic ferments act in an alkaline reaction, which is provided in the body by the sodium carbonate of the bile and pancreatic and intestinal juices.

21. Obtain a half pint of blood and whip it briskly with some small twigs. Fine threads of fibrin will collect upon the twigs. When the fibrin thus formed has been removed the blood will not coagulate upon standing.

22. The coagulation of blood can be observed with but a few drops of blood, if the blood is kept in a moist chamber to prevent drying. Prick the finger, which has been washed in alcohol, with a bayonet-pointed needle which has been passed through a flame to sterilize (kill all bacteria upon) it. Collect a few drops of blood upon a small butter plate. Invert this over a saucer of water and cover with a tumbler. In a half hour or less the blood will form a jellylike clot.

23. Test the blood serum (Experiment 20) for proteids. Heat test. Nitric acid and ammonia test (Xanthoproteic).

Test for sugar with Fehling's test.

Rub a little upon some paper. Does it appear to contain fat?

24. Defibrinate some blood by whipping it.

Pour off the defibrinated blood. Note its color.

Shake this in a bottle with air. What change occurs in the blood?

25. Corpuscles.

Prick the finger. Take a drop of blood upon a cover slip. Drop this blood side downward upon a glass slide. Examine specimen with a microscope (500 diameters).

Observe the red corpuscles.

Observe the white corpuscles. Look for one in motion (amœboid motion).

QUESTIONS

I. What are the two objects fulfilled by the food? What causes the constant wasting in the body? How do we know what substances must be present in the food to supply the body needs? Name some of the elements contained in the body substances.

II. In what form do we take the necessary nitrogen and carbon into the body? Why do we need compound substances for food? Give two objects accomplished by the use of organic foods. Mention some inorganic food substances. From what kingdoms of nature do most of our foods come directly?

III. Name the three classes of organic food substances. Which of these substances is the principal constituent of the body tissues? What foods contain proteid? What is the chief use of carbohydrates and

fats in the body? What foods contain carbohydrates? What foods contain fat?

IV. Can we live on any one of these three classes of food alone? Upon which one? Is it best to live on one kind of food substance? In what forms do we take water into the body? In what way do we get our mineral salts, the lime salts, chlorine, sulphur, iron, etc.?

V. How can we tell how much food we need? What is the effect of hard work upon the need of food? Explain why we employ a mixed diet. How does the food get to the tissues of the body? (Name the several processes through which it must pass in this course.)

VI. What is the object of digestion? What is the name of the digestive tract? Name the principal and accessory parts of this digestive system. What is a gland? What is the action of a gland called? In what does this process consist?

VII. Describe the contents of the mouth. Describe the teeth. How are the teeth fashioned according to their function? What is the saliva? Describe mastication. Describe the act of swallowing. Is it voluntary or involuntary? What parts does the food pass through in getting to the stomach?

VIII. What is the stomach? What is the lining of the stomach called? What structures lie in this membrane? What is the intestine? What is its length? What structures lie in or upon the membrane of the small intestine? Describe a villus. What is the function of the villi? What is a lacteal? What large external glands supply the intestine with secretions?

IX. What is the bile? Is the bile an excretion? What use is it as a secretion? What is the use of the gall bladder? What is the pancreas? What does it secrete? In what part of the intestine is most of the food absorbed? Where is most of the water absorbed?

X. What precautions in regard to the choice of food and the method of eating does the study of the organs of digestion suggest? Why do we cook food? Why do we have regular mealtimes? What are relishes? What is the effect upon the stomach of smoking? Is alcohol drinking likely to cause disorder of this organ?

XI. Describe salivary digestion. What class of food is digested by saliva? What is an unorganized ferment? Name the digestive ferment of the saliva; of the gastric juice. What food is digested by the gastric juice? What foods are digested in the intestine?

XII. What is the important digestive juice of the intestine? What other digestive secretions are found there? What is the action of rennin? Where does absorption occur? Describe absorption in the villi.

XIII. Through what two channels is the absorbed food borne away to the general circulation? Where is the food collected by the portal vein first carried? What occurs to the portal blood in the liver? Where does the food go from the liver? What becomes of the substances removed from the blood by the liver cells? What carries the food to the tissues?

XIV. Describe the blood. What is the function of the red corpuscles? Describe a leucocyte. What other functions has the blood besides bearing the food? Does the blood carry the food directly to the cells? What is coagulation? What is fibrin? What is the blood serum?

XV. What is the circulatory system? What becomes of the food when it reaches the capillaries? What is the difference between arterial and venous blood? Describe the lymph. Describe osmosis. What are the vessels which carry the lymph? Where is the waste collected by the lymph carried? Describe the course of the food from the mouth until it becomes a part of the tissue cells. What happens to the food in the cells?

XVI. Illustrate by examples how the anatomy of an animal may suggest the nature of his food. Is the solution of the food the only object of digestion? What other factor besides the physical factor enters into absorption? How may a failure to brush the teeth affect the health of the stomach?

CHAPTER VI

THE HYGIENE OF NUTRITION

THE VALUE OF THE DIFFERENT FOODSTUFFS FOR NUTRITION—CONDIMENTS AND BEVERAGES

WE have now studied the utilization of food in the body; how it is taken in and distributed to the tissues, and the changes which it undergoes in the process of metabolism. We understand why we eat food, and why we use the special substances which we do, the organic products, water, and salts.

We must now consider some of the more common articles of food, and study just what needs of the body each supplies and how each is disposed of in the organism.

Definition of a food. A food is any substance whose nature it is when taken into the body to serve for the growth or repair of tissue or for the production of energy to be utilized in the performance of normal functions.

Considered from a hygienic point of view, the term *food* means more than the above general definition indicates; it means a desirable food, a nourishing substance which can be recommended as a regular article of diet in normal conditions. There are substances which answer to the general definition of a food in that they are oxidized in the body with the production of energy, and yet cannot be considered as hygienic foods, since they exert a poisonous action which offsets what benefit the body might get from this oxidation.

Milk. One of the most common and useful articles of food is milk. This substance is the sole food of most infants during their first year of life. It must contain, therefore, all the substances which are necessary to build up the tissues and to produce energy in the body.

It should not, however, as has been said before, be used as the sole food of adults; for it does not contain the necessary substances, water, proteids, fats, and carbohydrates, in the proper proportions for the bodies of grown men. A man has to overwork his organs to get enough milk to provide his nourishment. Taken in proper quantity, however, there is no food more completely utilized in the body. Its proteid elements go to form tissue; its fats and carbohydrates are burned to produce energy. As a rule, it is very easily digested.[1]

Cream is the layer of milk which collects upon the top in standing. It contains much of the fat of the milk.

Butter is made from cream by churning it. It consists principally of fat and water. The fat of butter is in a very digestible and useful form.

Cheese is the proteid elements of milk separated. It contains some fat also.

Eggs, since they are really live animals in an early stage,

[1] Milk in standing about in pails and cans is sure to collect some of the many microörganisms which float about. Also the milk from cattle suffering from disease may contain the bacteria which cause their disease. One of the diseases which is borne in this way is tuberculosis.

To prevent the taking in of these bacteria of disease, or these hosts of other bacteria which may grow in the body and form substances which may poison the child, the milk to be given to children is often sterilized, or Pasteurized; that is, it is exposed to a heat sufficient to kill these bacteria before it is taken.

The Pasteurization of milk, which is the best method of preparing it for the use of children, is accomplished in the following manner: The fresh milk is placed in clean bottles which are stoppered with absorbent cotton. The bottles are placed in a steamer in which is a thermometer. The temperature of the steamer is raised to 167° F., and kept there from twenty minutes to half an hour. The bottles are then removed. Milk thus treated will remain sterile for twenty-four hours. The hot air in the steamer is, of course, moist.

must contain all the substances which are needed for the tissues. They are therefore an excellent food.

Meat. The muscular tissues of animals contain much proteid material, and are therefore very useful for building up and repairing the body tissues, which, as we have seen, consist mostly of this substance. The fat of meat is also a useful food.

Fish, like meat, contains much proteid substance.

Vegetable foods. Vegetables are a very necessary article of diet. Some of them contain all the substances which we need for both repair and energy, so that man can live in good health upon a strictly vegetable diet. This he could not do on lean meat, and would find very difficult upon milk. The most nutritious vegetable foods are the cereals or grains, and some leguminous seeds, as beans and peas. These contain much proteid matter for tissue building and much carbohydrate for energy formation, also mineral salts.

Of the grains those in most common use are the wheat from which flour for bread is made, and corn. Peas and beans are as useful for tissue building as meat, and more nutritious.

Many vegetables do not contain much proteid, and therefore are useful for their starch principally. Such are potatoes and rice. The green vegetables, as lettuce, spinach, cabbage, are useful for the mineral salts and organic acids which they contain, and for their indigestible matter (see note, p. 138). Where men are deprived of these or any substitute for them they are apt to contract a disease known as scurvy. Many vegetables are rich in iron, which is necessary for the structure of the blood corpuscles.

Fruits. Fruits, as a rule, contain much water and small amounts of nutritious principles. Apples, for instance, contain much water, some starch and sugar, and very little proteid. They are refreshing to the taste, and their large

amount of undigested residue makes them useful in keeping the bowels open. Bananas are fairly nutritious.

There are two substances, prepared from the seeds of the cocoa fruit, and now much used, which are very useful foods. These are *cocoa* and *chocolate*. They are nutritious, but with many people are difficult of digestion.

Water and salt. Besides these organic food substances we have two other important foods. *Water* is absolutely necessary to the organism. A man needs about four pints daily. Part of this water he gets with his solid foods, all of which contain a considerable amount of water. A certain amount, however, he takes separately. Besides the water of his food a man should take at least a quart of drinking water a day.

Salt is a mineral substance composed of chlorine and sodium. We need a good deal of both chlorine and sodium in the body as constituents of the tissues. A part of these substances we get from other mineral salts contained in our meat and vegetables, but most of them we get from this chloride of sodium, or common salt. Many foods already contain this salt; but, as a rule, we cannot get enough of it from our organic food, and have to add it to our dishes in cooking, or mix it with them on the table. It is so necessary that nature provides for our taking it by causing many foods, as meat, not to taste good without it. Animals need this substance as well as men, and travel great distances to get it.[1]

Other mineral substances, as lime for the bones, a man gets in organic foods, as milk and vegetables, which contain them.

The use of the different foods in the body. All these substances described and all substances which can properly be classed as foods supply the body with material for tissue

[1] In the woods or plains one sometimes finds moist, boggy spots or pools of water which contain much salt in the water or soil. These are "salt licks." The ground about will be found trodden with the marks of animals who come to get the salt.

building or for energy. The foods which contain proteids, as meats, bread, corn, peas, fish, eggs, milk, are very useful for tissue building. Those which are made up chiefly of sugar or starch, as potatoes, apples, rice, or of fat, as butter, fat meat, cream, are used mostly for energy. As we need both tissue and energy, we make our meals of combinations of these substances. Where we use up much tissue, as in active exercise, we eat more proteid food. Where we need more heat energy or body heat, as in cold climates, we eat more fat.

If we eat a sufficient amount of food made up from a combination of these substances which we have mentioned, meats, vegetables, milk, and so forth, we shall get all the material which the body needs.

These foods are all safe. They are suited to the organism and they nourish it. They can do no harm to the healthy body, unless they are taken in amounts larger than the organs can care for, or unless they are out of condition. Meats and milk and fruits and vegetables, when taken after they have begun to decay or ferment, often cause poisoning. But this is because the process of fermentation which brings about the decay in these foods changes their nature. From foods they are turned to poisonous substances.[1]

Even though they still may produce energy when taken into the body, they are no longer to be considered as foods, since their bad effects offset their useful ones. (See extract, p. 132, in regard to the definition of a food.)

Feeding with special foods or compounds. Much has been said about special foods being useful for the needs of sepa-

[1] The poisonous effects of tainted meats, milk, and other foods are due to substances formed from the fermentation or putrefaction of these foods by microörganisms. These are called ptomaines. Similar substances are formed in the body as the result of digestive processes, especially when the digestive processes are out of order. Sick headache and other illnesses are often due, in all probability, to the absorption of these substances thus formed in the body. In normal conditions the body destroys or eliminates them as fast as they are formed.

rate organs, as foods containing phosphorus for the brain, or lime salts for the bones. Now, while it is true that these organs need these substances, it is also true that they can get all they need of them from the proper mixture of the regular foods which we have described. Never in conditions of health make a point of taking foods especially rich in these substances, as you will often be advised to do. Especially is there no need of taking medical preparations and tonics to supply these substances. If the diet is a proper one, no deficiencies in these regards will exist. If such deficiencies are allowed to develop they should be remedied by making the diet a proper one. Even in conditions of disease a proper diet forms the best medicine in a great many cases.

A proper diet, in the first place, is one sufficient in amount to supply the needs of the body for tissue building and production of energy. This means that the day's diet must contain as much nitrogen, carbon, water, salt, iron, and so forth, as the man uses in his day's work. We can find out how much a man uses of these substances by measuring the amount that he excretes of each of them in his breathing, in his urine, sweat, etc. Then if we give him a diet which contains this amount of these substances, we know that he is having a sufficient diet and will be able to work and not fail in flesh and strength. Such a diet can be made up in various ways. All of us who are well fed are probably getting these proper amounts in our mixed diet of meats, milk, vegetables, bread, and so forth. If we are getting the full supply, it makes very little difference of what foods it is made up. We can get our nitrogen from meat or eggs or vegetables or cereals as we please, and take the carbon which we do not get at the same time in extra amounts of fats or other carbohydrate foods, as butter, cream, sugars, and bread.

Besides supplying the body with a sufficient amount of

food and a proper variety, it is best for us to give it also a certain extra amount of water and of substances which form refuse, as vegetables and fruits. These substances keep the system well washed out and clear. A plentiful number of vegetables and fruits should therefore be included in the diet. These contain much water, and often certain salts and acids which are useful in keeping the organs, as the liver and kidneys, well cleared out; and the large amount of indigestible residue left from them in the intestines helps to keep the bowels open.[1]

An example of a healthful diet for a man who works all day is given on page 140. Of course some people have what are known as idiosyncrasies, and cannot eat certain things which are readily digested by most people. People who are ill may need a diet made up of easily digested foods, but the amount should be about the same as in health. But except for such cases such a diet as is given in this table is a good one for anybody who works hard with body and mind.

The making of a diet list. Diet tables are made up upon what is known as the calorie system. The food is needed, as you know, for two purposes, one to build up proteid tissue, the other to be burned for the production of energy in the body. To provide for tissue building we must then see that our diet contains as much proteid or nitrogenous material as the body uses. To provide for energy we must see that the amount of food is so great that if burned it will produce just this energy as heat or something else.

A calorie is a unit of heat. We know just how many of these units of heat must be produced daily in the body

[1] As stated on page 104, foods which are easily digested are to be chosen. But a certain amount of undigested residue of the proper kind may be useful, as mentioned here.

to keep it going, and so we know how many heat units we must provide in the food. Now, heat units can be obtained from all organic foods, so that it does not matter very much, so far as this point is concerned, whether we eat meats or bread or vegetables or fat, provided we eat enough. But it is easier for our digestive organs to take care of a little of each of several foods than much of one kind, so we try to get our heat units from proteids and fats and carbohydrates combined.[1] Proteids we have to eat in certain amount for the nitrogen. The fats and carbohydrates we can divide as best suits our taste and digestion, provided only that we take enough of them.

In the following table the values of the foods included in proteid material for tissue building, in calories for energy production, and in mineral salts, are given. We know that a man at rest needs a food supply of 30 to 34 calories per kilogram weight. During hard work he needs a supply of from 45 to 60 calories per kilogram. When the food values in this table are added up they equal 80 to 130 gm. proteid (2½ to 4 oz.), 22 gm. salts, and 2,700 to 3,600 calories. As the daily needs of a workingman of average weight are from 80 to 130 gm. proteid, 25 gm. salts, and 2,500 to 3,500 calories, this forms an ample diet. It includes also a plentiful supply of vegetables, acids, and cellulose substances, which serve to keep the excretory functions of the body in good action. It includes a fair division of proteids, carbohydrates, and fats. The extra salt which is needed to make the 25 gm. is supplied by additions of table salt while the food is being prepared and at mealtime.

A diet of this kind supplies the body with a considerable amount of water. The remainder of water needed, about one quart, is taken by drinking water during the day.

[1] See note, page 91.

BREAKFAST

	Proteid, gm.	Calories.	Mineral Salts, gm.
200 gm. (about 6 oz.) porridge —oatmeal, rye, barley, Indian meal, or wheat	4–6	150–200	4
8 gm. sugar on porridge		8	.001
100 gm. milk on porridge	5–6	120–140	3
50 to 100 gm. bread, 1 to 3 slices	4–7	150–300	.5
15 gm. butter	.2	120	.5
2 eggs, or 50 gm. steak or chops	12	150–180	.5
Fruit—orange, apple, or grapes	0.5–1	50–150	.1
DINNER			
120 gm. consommé or chicken broth, or potato, pea, or tomato purée with salt	1–5	100–200	1
100 to 200 gm. beef, chicken, lamb, ham, or sweetbread	20–25	200–400	1
Or 200 gm. bluefish, salmon, halibut, cod, or mackerel.	12–20	150–300	
50 gm. potatoes	1.5	60	.5
100 gm. spinach, asparagus, or squash	1	100–200	.5
75 gm. peas, beans, macaroni, or corn	9–15	300	3
Custard, or ice cream, or Indian pudding, or rice or bread pudding	6–15	150–250	1
Cheese and crackers	2–5	300	1
SUPPER			
Bread and butter	5–7	200	1
Cocoa, one cup	6	150	1
Milk, one glass	8	200	3
Stewed fruit, pears, baked apples, peaches with cake, or griddle cakes	3–4	200–300	.1
Approximately,	80–130 gm.	2,650–3,600	21.71

In addition to his regular food man consumes certain substances, as condiments and beverages, which are not taken as food to nourish the body, but for the sensations which are obtained by taking them.

[1] 1 gm. = 15.434 grains troy.

Condiments. Some of these condiments are pepper, vinegar, cloves, nutmeg. They give the food certain flavors which excite the appetite and appeal to the sense of taste. Frequently, however, their use does harm, as they may set up irritation of the digestive organs and excite abnormal secretion. As already stated, a healthy man needs no stimulation for his appetite other than hunger.

Beverages. The common beverages which men take with their food or separately are *tea*, *coffee*, *cocoa*, or *chocolate*, and *alcoholic liquors*.

The alcoholic beverages, beer, wine, whisky, and so forth, are taken for the pleasure which they give from their taste and from their effect upon the nervous system. These substances cannot be recommended as foods. On the contrary, every one should be cautioned to avoid them; for the dangers which attend and the evils which result from their use are serious and out of all proportion to the benefits which this use can bestow.[1]

Our ordinary food substances, such as wheat, sugar, meat, give us our tissue material and our energy in the amount necessary for our nutrition without poisoning or danger of poisoning. These substances should therefore be chosen as foods, and not alcohol or any other substance whose use is fraught with danger.

If a person desires some other beverage than water with his food, he would best use cocoa or chocolate. These substances, as we have said (see p. 135), have a just claim to be considered good foods; they furnish at the same time

[1] It matters not that alcohol is oxidized in the body with the liberation of energy. So also are several of the organic poisons, as, for instance, muscarine, the active principle of the poisonous mushrooms. Yet no one thinks of classing these substances as foods.

Alcohol has a poisonous action, and since this action is exerted in such a way as to make the sum total of its effects harmful whenever enough is taken to prove a practical factor in energy production, alcohol should not be classed with the foods.

something which ministers both to the taste and to the needs of the body.

Tea and coffee are taken simply for their pleasurable effects. Since they do not assist in the nourishment of the body it is a question whether they should not be considered harmful to it in all cases; for they exact a certain amount of energy from the body in taking them in and disposing of them, while they give nothing substantial in return. In most cases, however, where they are taken in moderation, their harm is slight. With some people they are harmful even in moderate amounts. Taken in large amount, they are injurious to all people, causing a disturbance of the nervous system which is a menace to health and comfort. They should never be given to children.

QUESTIONS

I. What is the definition of a food? Name one or more single articles of food which contain all the materials necessary for the body needs. What is the objection to our living upon one of these foods alone? Why is milk for babies Pasteurized? What are the chief nourishing constituents of eggs? Meat? Fish?

II. How do the vegetable foods compare with the animal for general usefulness? Name some of the most nutritious vegetable foods. Why should we eat green vegetables and fruits? What use have these articles besides nourishment? How much water do we need daily?

III. Why do we salt our food? Mention some foods suited to particular purposes in the body. To what are the poisonous effects of decayed meats or vegetables due? Are such substances properly called foods? Do we need to take special foods to get the necessary mineral substances for the body? Give the requisites of a proper diet. How do we measure the efficiency of a given diet? Are condiments necessary? Name some of the common beverages. May any of these be classed as foods?

IV. Does alcohol provide material for repair of the body tissues? Does it increase the capacity of a man for continuous labor? Why should it not be classed with the foods? What is the chief and common object of the systems of digestion and circulation? Is meat a more valuable food than corn? Is any one food indispensable? Does eating fat result in the laying on of fat?

CHAPTER VII

ALCOHOL AND ALCOHOLIC LIQUORS

THEIR USE AND THE RESULTS UPON HEALTH

THE drinking of alcoholic liquors is so common and forms so serious an error in the maintenance of health that it merits special consideration in a book of hygiene.

Alcoholic drinks have been used by men for a very long time, and although some of their evil results have been seen throughout all this time, it is within recent years only that man has recognized, through careful investigation of the subject, the full extent of their harmfulness.

Now that their poisonous action is clearly recognized and understood, it is necessary that every one should have a knowledge of the nature of these substances and their effects upon the body, that through this knowledge he may avoid them, and thus escape the disease and degradation which fall upon so many people who use them, often in ignorance of their real nature and effects.

Alcohol, or in chemical terminology ethyl alcohol (C_2H_5OH), is a clear liquid substance looking somewhat like water. It has a characteristic odor and a burning taste.

Source of alcohol. Alcohol is obtained from sugar or substances containing sugar by a process known as fermentation (Latin *fermentum*, "leaven").

Alcoholic fermentation. It was long ago discovered that grape juice and apple juice (sweet cider) and many other substances containing sugar and water, if allowed to stand in the air, become changed in character. From a juice with a sweet taste the grape or apple juice becomes a substance with a sharp, burning taste. Now, upon comparing the new substance with the old, the wine or cider with the grape or apple juice, to see what alteration had occurred in it to cause this change in its nature, it was found that some of the sugar in the old juice had disappeared and been replaced principally by two new substances, a liquid, alcohol, and a gas, carbon dioxide. It was also found that the alcohol and carbon dioxide added together would make up, in a given instance, just the amount of sugar which had disappeared, except a very slight amount. It was therefore concluded that these new substances were formed by the breaking up of the sugar.

Cause of fermentation. Ferments. For a long time the cause of this breaking up or decomposition of sugar in these liquids was unknown. The amount of starch or sugar in apples or grapes kept intact a month does not change, nor does any alcohol appear in them. Finally, however, by the aid of the microscope it was found that those liquors which had undergone alcoholic fermentation, as the cider or wine, contained another new substance besides alcohol and carbon dioxide. In the liquid were found many minute, cell-like bodies which were not present in the juice as it was squeezed from the apple. These small bodies were found to be live organisms belonging to the vegetable growths classed by botanists as *Saccharomycetes*, and known in common terminology as the yeast plant. When some of these small bodies were put into a liquid containing sugar, and the liquor kept fairly warm, it was found that they act like a ferment, breaking up the sugar to alcohol and

carbon dioxide, that is, bringing about the same action which occurred in the cider. It was noted that the yeast plants in performing this function grow and multiply with great activity.[1] From this it was concluded that the small amount of sugar which disappeared from the liquor and could not be accounted for by the alcohol and carbon dioxide produced was consumed by the plant as food.[2]

The process was therefore all explained. These minute organisms or plants are floating about in the air or resting upon the skin of the ripening grapes or apples. When the grape or apple juice is pressed out, some of these yeast plants are washed into it, or fall into it from the air. Here they begin to feed upon the sugar in the juice, and grow and multiply, breaking up this sugar into alcohol and carbon dioxide and several other substances, and changing the apple or grape juice into cider or wine (Experiments 1, 2, 3, pp. 274, 275).

The process which thus occurs is called alcoholic or vinous fermentation.

The use of fermented liquors and of the process of vinous fermentation by man. As we have said, these products of vinous fermentation, the wines and cider, are used extensively by man as beverages. He takes them partly in conformity to custom and partly for the pleasure which they give him, oftentimes in ignorance of the fact that they are harmful substances.

The most common alcoholic beverages produced by this process of vinous fermentation are wine, beer, and cider.

Wine, as we have said, is a product formed by the fermenta-

[1] The yeast plants are little oval-shaped cells so small that they can be seen only by the use of a microscope. The ordinary yeast which is used by bakers in breadmaking or by brewers in beer brewing is simply a special preparation of these plants.

[2] Pasteur found that from five to six per cent of the sugar is used for food for the yeast plant and to form glycerin and succinic acid.

tion of expressed grape juice. It represents one stage in the process of the decomposition of this juice when pressed out of the fruit.

In the manufacture of wine, man crushes the grapes in a vat. Upon the skins of the grapes are many yeast spores.[1] These get into the juice in the process of crushing and mixing, and set up their vinous fermentation. Thus, as the juice lies in the vats, alcohol and carbon dioxide are formed in it, and it becomes wine. If there is sufficient sugar in the juice, the fermentation goes on until the amount of alcohol formed is about fourteen per cent. When the alcohol in a liquor reaches this strength it stops the action of the ferment upon the sugar. It poisons the ferment cell so that it cannot act, and no more alcohol is formed. The strength of alcohol in a fermented liquor may be anywhere from one to fourteen per cent. There are wines with a much greater per cent of alcohol, but in these the extra alcohol has been added.

Cider is formed by the fermentation of apple juice, as is wine from grape juice. Many people are under the impression that cider is a harmless beverage, but it is not. It contains alcohol like all fermented liquors, and from taking this small amount the formation of a permanent craving and an alcohol habit has often been developed.

Beer is manufactured by applying vinous fermentation to the decomposition of barley. In brewing beer, the barley, which contains starch, is kept in a warm place and moist until it sprouts. In the process of sprouting, most of the starch is turned to sugar. This step is necessary, as the yeast ferment will not act upon starch. After the sugar is

[1] The ferments found most generally upon the surfaces of grapes are *Saccharomyces* (sugar fungus) *ellipsoideus* (ellipse form). *Saccharomyces apiculati* (from *apic*, "point"), also found on grapes, is common on all garden fruits. *Saccharomyces cerevisiæ* (from *cerevisia*, "beer") is the ferment of beer yeast.

formed the grain is heated until it is killed, to stop its using up the sugar as a food for the young plant. The dead grains are then crushed, and the sugar is dissolved out by steeping in water. To this mixture of sugar and water, called beerwort, the brewer adds a substance called yeast, which is a mixture containing the yeast spores (*Saccharomyces cerevisiæ*), and which causes alcoholic fermentation.[1] The liquid then begins to ferment, the sugar is decomposed, and alcohol and carbon dioxide are formed. The alcohol collects in the liquor. The carbon dioxide, a gas, comes up through the liquor in bubbles, and passes off into the air. If the beer is bottled before the sugar is all decomposed, the gas is contained in the liquor, and begins to escape when we open the bottle, thus causing the fizz and foam of the beer.

The making of bread involves the application of the process of alcoholic fermentation, which here man has turned to a useful purpose. To the mixture of flour and water, the dough, some yeast is added. This ferments the sugar in the dough, forming alcohol and carbon dioxide. The gas goes through the dough, raising it. When the bread is risen it is baked. This drives off the alcohol and expands the gas, which fills the bread with small bubbles or holes, and stops the action of the yeast. There is therefore no alcohol in bread that is properly baked.

The product of fermentation contained in these fermented liquors to which all the harmful effects of the liquors are due is the alcohol. This alcohol can be separated from the liquors by a process known as distillation. This process is employed in the manufacture of the beverages called hard liquors, such as whisky and brandy.

Distillation. In the liquor the alcohol is mixed with many other substances, as water and sugar, which are less volatile than alcohol. That is, if the liquor is heated, alcohol is

[1] Pure yeast ferments sugar only. Mixtures of yeast often contain bacteria, which have a diastatic action upon starch and turn it to sugar, so that the yeast can act upon it. In breadmaking, some of the starch is changed in this manner, and the sugar formed is fermented by the yeast.

converted to vapor at a much lower heat than is necessary to convert the water to steam. Consequently the alcohol will turn to vapor and pass off before much of the water has become hot enough to form steam. Thus, by heating we can separate the alcohol from the water and more solid substances. Now, if this alcohol vapor is allowed to collect in a cold vessel, it will condense, and we shall have the liquid alcohol. This process of separating alcohol is called distillation. The liquor is heated in a closed vessel with a pipe running from it which bends downward and empties into another vessel. The pipe, or worm, is kept cool by a current of cold water. The vapor of the alcohol rises until it is past the bend, then is condensed by the cold, and falls in drops upon the sides of the pipe, and runs into the receiving vessel.

Distilled liquors. The distilled liquors which are manufactured by this process, the whisky, brandy, rum, or gin, contain much more alcohol than the simple fermented liquors from which they are distilled. In the process of their distillation some water and also some extracts pass over into the distillate. These extracts give the peculiar flavor to the different liquors.

Because these so-called hard liquors contain more alcohol than the fermented liquors, they are more harmful; but it is only a question of degree in regard to all alcoholic liquors, beer or cider, whisky or rum. The alcohol contained in any of these liquors is, when introduced into the body, capable of poisoning it. Those who have once seen men under the effect of this substance need no further evidence of its poisonous power. Its poisonous effects, however, are not confined to these cases where they are so marked as to be plain to every observer, cases where men lose their reason, their power of coördination and locomotion. A careful study of the effects of alcohol in the body reveals, as we shall see, that its

action is often insidious, often for a long time giving no sign, even to the drinker himself, of the poisonous effect upon his health and strength that it is exerting.[1]

THE ACTION OF ALCOHOL WITHIN THE BODY UPON THE VITAL FUNCTIONS

When any alcoholic liquor is introduced into the body, a portion of the alcohol is oxidized there. In being oxidized, alcohol is broken up into water and carbon dioxide, and the energy contained in the compound is liberated. Some of the alcohol, however, passes through the body unchanged, and is eliminated in the urine and the breath.

The action of alcohol upon the constitution and functions of the body is a complex one. To some extent, as stated, it liberates energy for the performance of the vital functions, that is for heat or work; but it also acts upon the nervous system, or upon cellular activity throughout the body, in a manner detrimental to these functions.

[1] Dr. Adolf Fick, Professor of Physiology in Würzburg, Germany, says: "From an exhaustive definition we shall have to class every substance as a poison which, on becoming mixed with the blood, causes a disturbance in the function of any organ. That alcohol is such a poison cannot be doubted. . . . Very appropriately has the English language named the disturbance caused by alcoholic beverages *intoxication*, which, by derivation, means poisoning."

Ethyl alcohol, even when diluted as in wine, beer, and cider, is a poison which changes pathologically the tissues of the body and leads to fatty degeneration. Of course I am not speaking here of the smallest doses. However, the latter (for example, half a liter of beer or a glass of wine) are also poisonous, because they injure the brain by producing paralysis and derangement of function; that is clearly demonstrated by the experiments of Kraepelin, Smith, Fürer, Aschaffenburg, etc. The same have never been controverted. The most moderate drinking of alcohol is quite useless for the individual, but by means of example and fashion produces an incalculable social injury and misery to the masses, since all cannot remain moderate, and the entirely moderate remains at last the exception.—Dr. August Forel, Professor of Psychiatry in the University of Zurich.

All the alcohols are poisons.—Dujardin-Beaumetz and Audige.

Is alcohol a poison? I reply, Yes. It answers to the description of a poison. It possesses an inherent deleterious property which, when introduced into the system, is capable of destroying life, and it has its place with arsenic, belladonna, prussic acid, opium, etc.—Dr. Willard Parker, late Professor of Surgery in the College of Physicians and Surgeons, New York; Consulting Physician to Bellevue, Mount Sinai, Roosevelt, and the New York hospitals.

It is our concern in the study of hygiene to determine, if we can, just what the sum total of its effects is, when taken in the amounts and manner in which it is ordinarily used by men as a beverage. In other words, we wish to know whether the balance of its various separate effects upon the vital functions of the body is helpful or harmful.

Effect upon vital functions. We know that if strong alcohol is applied to the cells of a growing plant, or to the body cells uncovered in a wound, these cells are deprived of their vitality and finally die. Doubtless this would be the effect of alcohol upon living cells anywhere in the body, if it reached them directly and in full strength; but when taken in beverages it does not reach the body tissues in full strength, but much diluted. What we want to determine, therefore, is whether the effect of alcohol in this diluted form in which it circulates in the body of men who use it as a beverage is also a deleterious one upon the vitality and function of the cells therein.

The way to determine this question is to study the effects of alcohol upon the persons who drink it. In this investigation we at once find evidences of this deleterious action. These evidences are, of course, most marked in the cases of persons who drink large quantities of liquor. Here we find marked disturbance of the functions of the brain, the digestive organs, the heart, loss of vitality of the tissues during life, and degeneration of these tissues in the examination after death. But the evidence of deleterious action is not confined to these cases of hard drinkers. It is found also in the cases of men who drink alcohol in such small quantities, for instance, as are ingested in the practice of what is commonly called "drinking in moderation."[1]

[1] All alcohol, and all things of an alcoholic nature, injure the nerve tissues *pro tempore*, if not altogether, and are certainly deleterious to the health. I think there is a great deal of injury being done by the use of alcohol in what is supposed by the consumer to be a most moderate quantity, to persons who are not in the least intemperate,

This evidence, which tends to show that the drinking of alcohol even in moderation is injurious, is best obtained in the investigation of the effect of this drinking in moderation upon two of the vital functions of the body, that of muscular work and that of maintaining the body heat.

The end and aim of all the body processes is to work. To accomplish this end the body must keep warm. The more perfectly the body can accomplish these conditions, the more able is the possessor of that body to make his way in the world. Now, alcohol, taken even in what is considered moderation, lessens the power of the body to work and to maintain its heat supply.

This conclusion is based upon experiments conducted upon large numbers of men during long periods of time. The results in regard to the effect of alcohol upon the capacity for work were obtained from investigations in the large armies of the world during active campaigns (see p. 80). Those in regard to the effect upon the maintenance of the body heat were obtained in part from scientific investigations carried on by physiologists in all parts of the world, in part from investigations conducted among the members of companies of arctic explorers.

In the light of our present knowledge, then, it is evident that alcohol as a beverage lessens the usefulness of the body.

A certain amount of alcohol is undoubtedly oxidized, and can be utilized for the production of energy for the body; but in the ordinary conditions of labor and exposure to which man is subjected, the benefit which the body can receive from it, in cases where enough alcohol to prove a practical factor in energy production is taken, is more than offset by

and to people supposed to be fairly well. It leads to degeneration of the tissues; it damages the health; it injures the intellect. Short of drunkenness, that is, in those effects of it which stop short of drunkenness, I should say from my experience that alcohol is the most destructive agent we are aware of in this country.—Sir William Gull, M.D., F.R.S., Consulting Physician to Guy's Hospital, London.

the deleterious effect of the alcohol. The sum total of the effect is therefore harmful.

In addition to evidence obtained by physiological investigations, we have the evidence of statistics in regard to the health and mortality of people who use alcohol, and of those who do not. These have been collected in England by the life-insurance companies. They indicate that the life of the abstainer is, on the average, longer than that of the drinker.

Also, it has been found that the hospitals get their inmates to a much greater extent from the drinkers than from the abstainers. The drinker is less able to resist infection, and the physicians of these hospitals all acknowledge that, once infected with a serious disease, the chances of the alcohol drinker are much less than those of the abstainer.

In regard to sunstroke, for instance, a condition which is so common in our great cities during the summer months, Osler, in his "Practice of Medicine," makes the following statement: "In the larger cities of this country the cases [of sunstroke] are almost exclusively confined to workmen who are much exposed, and at the same time have been drinking beer and whisky." [1]

In addition to what directly harmful effects alcohol may have upon the health through its action upon the tissues or body functions, its use has another possible effect, which has to be taken into account in any consideration of this use from a hygienic point of view. This effect is the formation of what is known as the *alcohol habit.* A description of this deplorable condition is given in the sections on alcohol and the alcohol habit in Chapter XI. It is sufficient merely to mention it here as one of the dangers attending the use of alcohol.

[1] The late Surgeon Parke, medical officer of the Emin Pasha relief expedition, said: "Drink is certainly the most powerful predisposing cause of the development of the symptoms of sunstroke."

The indulgence in any practice involving risk from the point of view of health or welfare is justifiable only in cases where the benefit to be derived from the practice is proportionate to the risk involved, and where the same benefit cannot be obtained in some manner involving less or no risk. The danger of the use of alcoholic drinks, and the harm which may follow this use, are, in a general average, out of all proportion to the possible benefit which is or can be derived from it. This use is therefore unjustifiable, and should be condemned in all manuals of hygiene.

QUESTIONS

I. What is the source of alcohol? Describe the fermentation of alcohol. What is the cause of this process? What is beer? Wine? Cider?

II. What are distilled liquors? Describe breadmaking. What are some of the harmful effects of the drinking of alcoholic liquors upon the vital functions of the body? Give the principal reasons for avoiding the use of alcoholic beverages.

CHAPTER VIII

CIRCULATION AND THE CIRCULATORY SYSTEM

WE have already spoken of the circulation of the blood and lymph in describing its connection with the distribution of the nourishment to the tissues. Besides this use, the circulation has two other functions. One is the bearing of the free oxygen to the tissues, the other the carrying away of the waste products of tissue combustion to the excretory organs.

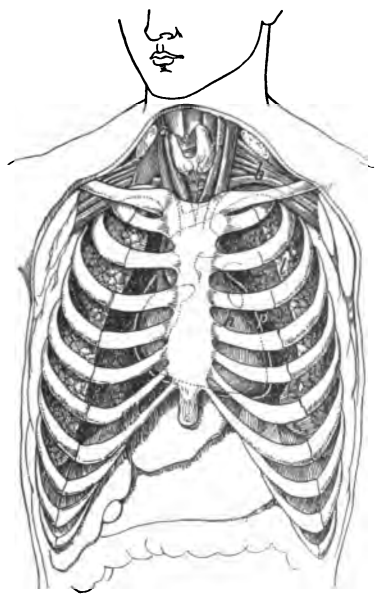
We must now study the organs by which this function of circulation is accomplished. These are the heart, which pumps the blood about the body; the blood vessels, which carry this stream of blood; and the lymphatics, which carry the lymph.

I. THE HEART

The *heart* is a hollow muscular organ, whose function it is to pump the blood about the body. It lies in the thorax, just above the diaphragm, behind the sternum and the rib cartilages on the left side. It is attached at its base to the great vessels.

The pericardium (Greek *peri*, "around," and *kardia*, "heart"). Inclosing the heart is a sac called the pericardium. This sac lines the heart externally, and then leaving it at the base, folds upon itself and completely surrounds it again.

The pericardium is a connective tissue structure lined upon its free surface by a thin membrane of epithelial cells known as a *serous membrane* (a membrane made up of cells which discharge a serumlike or wheylike substance). These free surfaces of the two parts of the pericardium, the part lining the heart and the part forming the sac, move freely upon each other with the movements of the heart. The cavity between them contains a little fluid secreted by the cells of the serous membrane.



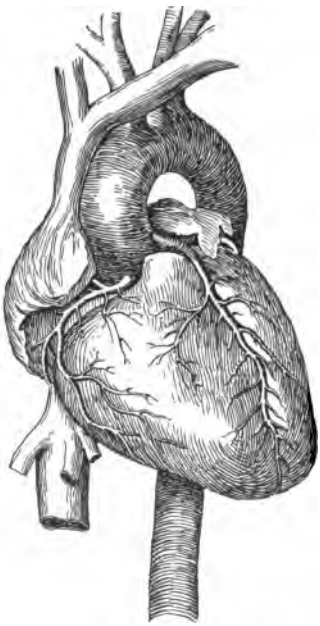
Heart and lungs in chest.

a, arteries and veins to head (right); *b*, arteries, veins, and nerves to arm (left); *h*, heart; *l*, lung (drawn back); *p*, pericardium.

The heart is conical in shape, the broad end, or base, uppermost, the cone end, or apex, below. The apex lies opposite the point of the chest wall at which we can feel the heart beat most strongly, between the fifth and sixth ribs to the left of the sternum. At the base of the heart the large arteries run out. Here at the base on each side is a flat, soft, earlike structure connected with the firmer part below. These flabby structures are the appendages of the *auricles* (Latin *auris*, "ear") of the heart. The firmer parts below inclose the *ventricles* (Latin *venter*, "belly").

The heart consists of four chambers—two auricles, right and left, and two ventricles, right and left. At the base,

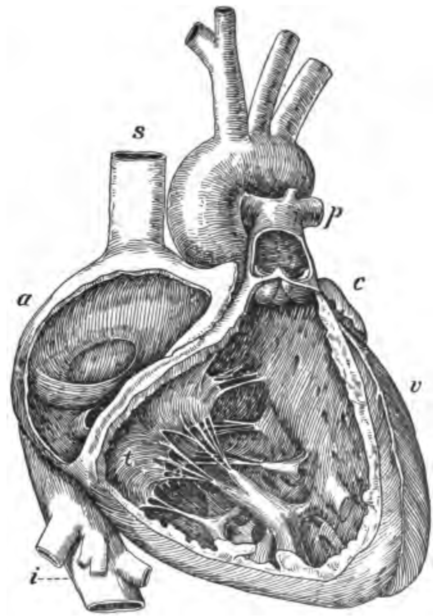
posteriorly and to the left, lies the left *auricle*. In the comparatively thin walls of this cavity are four small openings, the apertures of the pulmonary veins, which bring the blood from the lungs. In the lower wall of the auricle is a large opening to the left ventricle.



Heart, with aorta.

The *left ventricle* lies in the lower part of the heart, to the front and left. The walls of this cavity are very thick and firm. Upon its upper wall is the opening from the left auricle. This opening is covered by a valve made up of two flaps, the bicuspid or *mitral* (Greek *mitra*, "head-dress") *valve*. The bases of these valve flaps are fixed about the auriculo-ventricular opening. Their edges are held by connective tissue cords connecting with the ventricular walls, the *chordæ tendineæ* (Greek *chorda*, "cord," and *tenein*, "to stretch"). These cords keep the valve from pressing back into the auricle under the pressure of the blood in the ventricle. The valve allows the free flow of the blood from auricle to ventricle, but stops any back flow from the ventricle when the ventricle contracts. In the front part of the ventricle, in front of the auricular opening, is the opening to the aorta. This opening is covered by a valve consisting of three flaps, each shaped like a half moon, the *semilunar* (Latin *semi*, "half," and *luna*, "moon") *valve*. This valve allows the blood to flow from the ventricle to the aorta, but not back from the aorta.

At the base of the heart, to the right, separated from the left auricle by a partition or septum, is the *right auricle.* In the right wall of this auricle is the opening of the two large veins which collect the blood returning from the tissues to the heart, the *superior* and *inferior vena cava* ("hollow").



Interior of heart, showing right auricle and ventricle and valves.

a, auricle; *c*, semilunar valve; *i*, inferior vena cava; *p*, pulmonary artery; *s*, superior vena cava; *t*, tricuspid valve; *v*, ventricle.

In the lower anterior part of the auricle is the opening of the right ventricle. This is covered by a three-flap valve, the *tricuspid* (Latin *tri*, "three," and *cuspis*, "spear point") *valve.* It prevents *regurgitation* (Latin *re*, "again," and *gurgitare*, "to engulf") of the blood from ventricle to auricle.

The *right ventricle* lies in the lower part of the heart, to the right. It is separated from the left ventricle by a septum. The walls of this ventricle are thicker and firmer than those of the auricle, but less thick than those of the left ventricle. At the top of the ventricle, toward the front, is the opening to the pulmonary artery. This opening is covered by a set of *semilunar valves* similar to those of the aortic aperture.

Structure of the heart. The heart is composed of muscular tissue of a special kind, described in the chapter upon the muscles. This muscular wall is lined without by the cardiac layer of the pericardium, within by a membrane known as the *endocardium* (Greek *endon*, "within," and *kardia*, "heart").

Heart valves.

This membrane has a single layer of epithelial cells upon its inner surface, and is continuous with the inner lining of the arteries and veins, the *endothelium*.

The valves are formed of connective tissue lined with the endocardium.

The heart is nourished by arteries from the aorta, known as the *coronary* (Latin *corona*, "crown") *arteries*. Its action is controlled by a special plexus of nerve ganglia (Greek *gagglion*, "ganglion"—"a knot"), located in its substance and connected with the central nervous system.

The action of the heart. The action of the heart is brought about by the contraction of its muscular walls. When the muscle fibers contract they become shorter and thicker, and thus diminish the size of the cavities which they inclose. By the same muscular action the walls of the cavities are drawn toward each other as well as contracted. Thus, when a contraction of the walls of a cavity occurs, the cavity is nearly obliterated, and the blood forced out of it, just as squeezing a rubber ball with a hole in it obliterates its cavity, and forces any fluid in it, as water, out.

The contraction of the heart walls is called a *systole* (Greek *sustole*, "a contraction"). When the walls have thus con-

tracted they relax again, opening the cavities and allowing an inflow of blood from the veins. This relaxation is called *diastole* (Greek, "dilatation").

Now, in the action of the heart, the two auricles contract together, and this is followed at once by a contraction of the ventricles. Then there is a pause during which the heart relaxes and the cavities all open again, then a contraction again, and so on. These rhythmic contractions of the heart make what is known as the *beat* of the heart. This beat can be felt, especially after exertion, as a thumping of the heart against the chest wall (Experiment 3, p. 34).

The *sounds* of the heart, which you can hear by laying your head, ear down, upon the pillow, are two—a long one, like *lub*, followed by a short one, *dup*. The first sound is due to the contraction of the heart, the second to the closure of the valves.

The passage of the blood through the heart. At the beginning of the heart beat the auricles contract. The right auricle, which has filled with blood from the large veins of the body, the *venæ cavæ*, contracts and forces the blood into the right ventricle. This contraction of the auricle closes the flaccid openings of the veins in its walls, so that none of the blood is forced back into them, but all onward.

As the auricular contraction ends, the right ventricle, which thus has been filled with blood, takes up the contraction, forcing the blood into the pulmonary artery, and thus into the lungs. The whole contraction of both auricle and ventricle passes over the heart like a wave, starting at the auricular end and ending at the ventricular.

In the contraction of the ventricle, the flaps of the tricuspid valve close the auricular orifice and prevent a reflex of the blood from the ventricle in this direction, so that it can go on only into the pulmonary artery.

While the ventricle is contracting, the auricle is relaxing,

and as it does so a new supply of blood flows into it from the veins. This blood in turn is forced into the ventricle as this relaxes, and so on through beat after beat. In the relaxation of the ventricle, the semilunar valve of the pulmonary artery is closed over the orifice by the back pressure of the blood in the overfilled artery, and thus the back flow of blood into the ventricle is prevented.

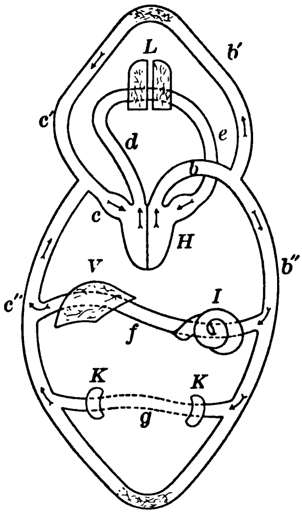


Diagram of the circulatory system.

H, heart; *L*, lungs; *I*, intestine; *V*, liver; *K*, kidneys; *b*, aorta; *b′*, arteries to head and upper extremities; *b″*, arteries to trunk and lower extremities; *c*, venæ cavæ; *c′*, veins from upper extremities; *c″*, veins from lower extremities; *d*, pulmonary artery; e, pulmonary veins; *f*, portal circulation; *g*, renal circulation.

The blood is forced along the pulmonary artery to the capillaries of the lungs by the force of the beat of the ventricles, and from these capillaries into the pulmonary veins, and so back to the left auricle of the heart.

At the same time that the right auricle is contracting upon the blood of the general circulation which it has received, the left auricle is contracting upon the blood which it has received, as above described, from the lungs by the pulmonary veins. This blood it forces into the left ventricle. The left ventricle contracts at the same time with the right, and presses the blood past the semilunar valves into the aorta, and thus into the general circulation. The pressure of the blood upon the mitral valve closes it, and prevents regurgitation of the blood into the auricle. When the ventricle dilates again, the semilunar valve of the aorta prevents reflux of the blood to the ventricle.

The impulse of the left ventricle forces the blood along

the aorta to the arteries and capillaries throughout the body. From the capillaries it is returned by the veins to the right auricle, thence as described to the right ventricle, lungs, and left auricle, and into the ventricle again. Thus by the impulse of the heart the blood is kept flowing in a big circular course over the body.

Work of the heart. The heart beats seventy times a minute. At each beat each ventricle forces six ounces of blood along against the back pressure of the blood in the vessels. When all this work is calculated, it will be found that the heart in one day does work equal to raising a ton of coal nearly two hundred feet.

II. THE BLOOD VESSELS

The vessels which carry the blood in its course around the body are divided into three classes.

The *arteries* are the vessels which carry the blood from the heart to the capillaries and tissues.

The *capillaries* are very fine vessels which carry the blood from the arteries through the interstices of the tissues.

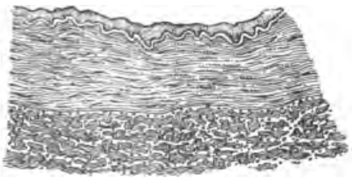
The *veins* carry the blood from the capillaries and tissues back to the heart.

(See plans of arterial and venous systems, pp. 164, 165.)

Structure of the vessels. The whole circulatory system is one continuous tube. The endocardium, or inner lining membrane of the heart, is continued throughout the arteries, capillaries, and veins. In the vessels it is called the *endothelium.* This endothelium, like the endocardium, consists of a single layer of epithelial cells. The walls of the capillaries, the smallest vessels, consist simply of this endothelial membrane. In the small arteries a layer of muscular and elastic tissue is placed outside this endothelium, and a connective tissue layer outside of this. In the large arteries

the muscular layer is very thick and contains much elastic tissue.

The arterial walls consist, then, of three layers: first, an endothelial; second, a muscular and elastic; third, a connective tissue layer. The elastic tissue makes the arterial wall very firm and elastic. When an artery is cut it does not collapse, owing to the firm tissue in the walls.



Wall of artery.

The walls of the veins consist of three similar layers. They contain, however, much less muscular and elastic tissue, and thus collapse when cut.

Plans of the arterial and venous systems. The *arterial system* begins with the aorta (1).[1] This vessel leaves the left ventricle at the base of the heart and runs upward, forming an arch in the upper part of the chest.

From the convexity of this arch arise three large arteries—the *innominate* (2) (Latin *in-nomen*, "unnamed"), which divides into two trunks, the *right carotid* (5) (Greek *karos*, "stupor"), which supplies the neck and head, and the *right subclavian* (6) ("under the clavicle"), which supplies the shoulder, arm, and hand on the right side; the *left carotid* (3), which supplies the left side of the neck and head; the *left subclavian* (4), which supplies the left upper limb. Each subclavian runs across the armpit as the *axillary* artery, then down the arm to the elbow as the *brachial* (Greek *brachion*, "arm"), dividing there to the *radial* and *ulnar* arteries to the forearm and hand. From the arch the aorta runs downward along the front of the spine as the *thoracic aorta* (7), giving off branches to the walls of the thorax. Piercing the diaphragm, this artery becomes the

[1] Figures refer to plate of the circulatory system, page 164.

abdominal (Latin *abdere*, "to conceal") *aorta* (8), which gives off the *cœliac* (Greek *koilia*, "belly") *axis* (9) to the stomach, liver, and spleen, the *mesenteric arteries* to the intestines, the *renal arteries* (10), and several smaller branches.

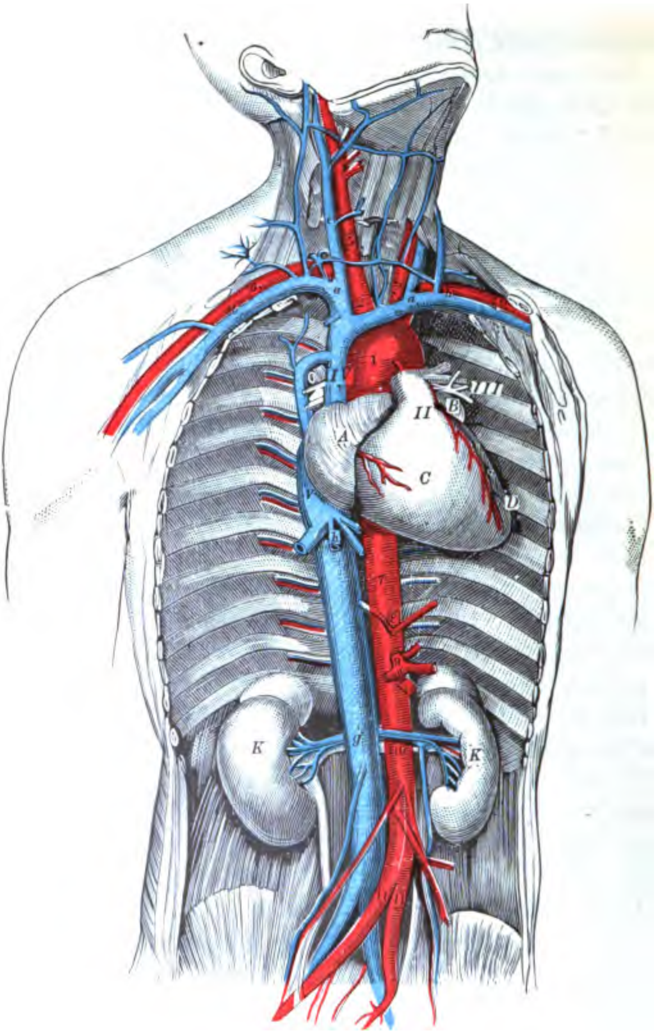
At the level of the fourth lumbar vertebra the abdominal aorta divides to take two *common iliac* (Latin *ilia*, "flanks") *arteries* (11), a right and left. Each iliac artery supplies its side of the pelvis and continues into the leg, being called the *femoral artery* in the thigh and the *popliteal* (Latin *poples*, "the ham") at the knee. This artery divides to the *peroneal* (Latin *perone*, "fibula") and the *posterior tibial*, which supply the leg and foot.

The veins begin as small twigs collecting the blood from the capillaries. These small branches coalesce to larger trunks until finally the venous blood is collected into the two large veins, the *superior vena cava* (IV) and *inferior vena cava* (V), which pour it into the heart.

The blood from the head and neck is brought by the *jugular* (Latin *jugulum*, "throat") *veins* (*c*) to the chest. The blood of the hand, arm, and shoulder is brought to the chest by the *subclavian vein* (*b*). In the chest the jugular and subclavian veins of each side unite to form the *innominate* (*a*). The two *innominates* thus formed unite to form the *superior vena cava* (IV), which runs to the heart. The intercostal spaces are drained by the *azygos* (Greek *a*, "without," and *zugos*, "yoke") *vein*, which enters the superior vena cava.

The veins of the lower limbs unite to form the *inferior vena cava*. This receives the veins from the pelvis, the kidneys (*g*) (renal veins), and the liver, and enters the heart.

The blood from the alimentary tract, the stomach and intestines, and that from the spleen is collected by the *portal vein*. This carries it to the liver, where the vein divides into fine capillaries like an artery. The blood from the capillaries, purified by the liver cells, is again



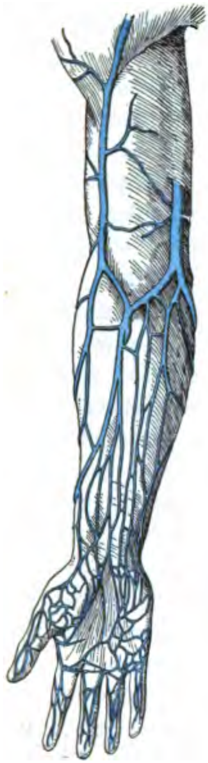
The circulatory system.

A, **right auricle;** ***B***, **left auricle;** ***C***, **right ventricle;** ***D***, **left ventricle;** ***K***, **kidneys.**

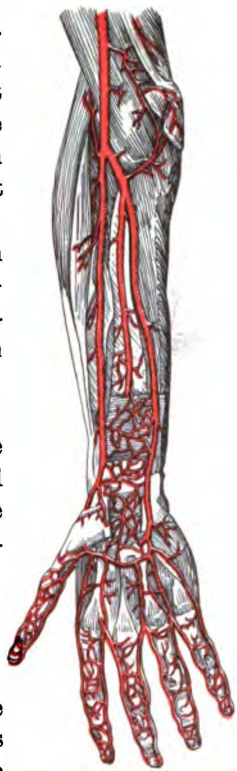
collected by the hepatic vein, which enters the inferior vena cava (*h*).

The pulmonary circulation. In addition to this general system of circulation, there is a subsidiary system, the *pulmonary* (Latin *pulmo*, "lung") *system*. The venous blood returned to the heart has to be sent to the lungs for purification before it is again sent through the body.

The blood is taken from the right ventricle by the *pulmonary artery* (II), which divides in the lungs, to capillaries. From these capillaries the blood is collected and borne back to the heart by the pulmonary veins (III).



Veins in arm and hand.



Arteries in arm and hand.

III. THE LYMPHATICS

The lymph, like the blood, circulates in vessels. These are called *lymphatics*. In the tissues, the lymph is free in the spaces among the cells. These spaces are drained by a network of delicate vessels. These lymphatic vessels, like the veins, unite to form larger ones, until finally

the lymph is collected into a left and right vessel of large size, which empties it into the veins. The large trunk of the left side is called the *thoracic duct.* This receives the lymph from both lower limbs, the abdominal viscera, and the left thorax, arm, and side of the head.

Lymphatics of arm.
a lymphatic nodes of axilla.

In addition to the lymph from the tissues, the lymphatics carry to the veins the chyle, which is absorbed from the intestines. This chyle is the part of the food which absorbs into the lacteals, one of which runs in the center of each villus. These lacteals run into larger trunks, which finally enter the thoracic duct.

In *structure* the walls of the lymphatic vessels are composed of an endothelium, a muscular layer, and a connective tissue layer.

The flow of the lymph in these vessels is due to the pressure in the tissues, where, as described, there is a constant overflow of lymph.

Lymphatic nodes. In the course of the lymphatics are numerous structures known as *lymph nodes* or *lymph glands.* These nodes consist of clusters of cells bound together by connective tissue. They are a part of the lymphatic tubes, filled with cells, through which the lymph filters in its course. In this passage through the node the lymph is purified, certain of its contents being taken out or worked

over by the gland cells. The lymph also takes up cells from these nodes, which are thus poured into the blood and become the white corpuscles there, since these corpuscles, many of them at least, are simply free lymph cells. These nodes are called glands, in many books, but are not glandular structures.

The spleen. There is one large and important structure in the body classed with the lymph nodes. This is the spleen. It is often called a ductless gland.

The spleen is a dark purplish-red organ about five inches in length, situated on the left side of the abdomen, just inside the lower ribs.

In *structure* the spleen is a big lymph node. It consists of a connective tissue framework like that of a sponge. In the meshes of this spongy frame is a soft pulp, the spleen pulp. This pulp consists of red blood corpuscles, of white blood corpuscles, and other cells. Throughout the spleen are small white nodules consisting of groups of leucocytes. Here in the spleen these white corpuscles multiply, and then are poured into the blood as white blood corpuscles, just as they are poured into the lymphatics from the lymph nodes. The red corpuscles which have been used in the blood are probably collected and broken up here.

The spleen is supplied by an artery, and its vein empties into the portal system. The blood flows freely through the pulp, permeating it everywhere.

IV. THE METHOD OF THE CIRCULATION THROUGH THE VESSELS

In the circulation the blood is forced through the series of elastic tubes, the arteries, into the smaller capillaries. The passage of the blood through these vessels, particularly

the great number of minute capillaries, gives rise to much friction. This friction is the resistance which the heart has to overcome by its impulse. The vessels are always full of blood. The aorta and arteries are kept more than full—distended.

This pressure on the walls by the excess of blood in the vessels is called the *blood pressure.* The distended elastic walls are constantly tending to contract to their regular size, and in so doing they are exerting a constant pressure upon the blood within the vessels, forcing it onward into the capillaries and veins.

The distention is kept constant by the supply of blood which the heart is regularly pumping in. Thus during life there is always a distention of the vessels, with a constant flow along them in the direction of the capillaries and veins (Experiments 3, 4, p. 177).

When the heart pumps, the distention is increased momentarily, and there is a spurt of blood into the small vessels. Thus, when an artery is cut, the blood will flow in a continual stream, but with this there will be at regular intervals an extra flow or spurt.

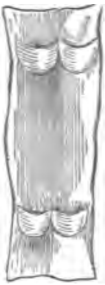
When the blood gets to the veins much of the force has been used up in friction, so that the blood flows under less pressure here.

The whole flow of the blood is due to the pumping of the heart. This flow is regulated and guided, however, by the muscular, elastic walls of the vessels.

The pulse. When the heart pumps the blood it causes a distention of the walls of all the arteries. Where a large artery runs near the surface of the body, as the radial artery in the wrist, we may feel this wave of distention with the finger. This we call the *pulse.* This pulse does not extend to the veins. Here the blood flows steadily, but with very little force, as a large amount of force is used up in the fric-

tion of the passage through the capillaries. What remains, however, serves to take the blood back to the heart.

The valves of the veins. On account of this low pressure, the veins, especially those of the limbs, are provided with valves which open to the blood flowing toward the heart, but close against any back flow, and thus tend to keep the blood flowing in one direction under all conditions. The position of these valves in the superficial veins of the front forearm may be seen by exercising the arm, and then compressing it at the wrist. The valves appear as little swellings in the course of the blue veins.



Valves of veins.

The vasomotor (Latin *vasa*, "vessel," and *moveo*, "I move") **regulation of the circulation.** We have said that the blood vessels of the body are always full. This universal fullness is maintained by an *automatic* (Greek *auto*, "self," and *matos*, "spontaneous," "self-acting") regulation of the caliber of the vessels in different parts of the body, in accordance with the amount of blood in them.

There is not enough blood in the body to keep all the vessels distended if each is relaxed to its full extent. But they are never all thus relaxed. Each artery adapts its size to the amount of blood in it, so as to have its walls always distended. Thus, if one drachm of blood is in a vessel, the vessel contracts so that it holds without distention less than a drachm. The presence of the drachm, therefore, causes a distention of the walls.

This regulation of the caliber of the vessels is controlled by the muscular tissue in the walls of the vessels. The whole system of regulation is controlled by the vasomotor nervous mechanism.

This regulation is in constant operation in the accomplishment of the various functions of the organism. Through

it, the supply of blood is concentrated in active organs of the body. Thus, after dinner a large supply of blood is needed in the stomach and intestines, and the arteries of this region are therefore dilated to their full capacity, and filled with an extra supply of blood. This extra supply is drawn from the quota of other regions, as the brain and limbs, which are in rather diminished activity at this time, the vessels in these parts contracting in proportion to their diminished contents. If, however, a man uses his brain actively or exercises vigorously at this time, the brain and limbs will keep their full supply of blood, and the stomach will not get the extra blood which it needs, and thus the process of digestion will not go on as it should. We all have an illustration of this process in the flushing of the face and beating of the arteries of the head during mental excitement.

V. HYGIENE OF THE CIRCULATORY SYSTEM

There is a saying among physicians that a man is as old as his blood vessels. Certainly, any man who has a weakened or diseased heart or unsound vessels is old before his time. He is less fitted for work of any kind, and is more susceptible to disease, than a sound man of his age.

The care of these organs should be a simple thing. The regulation of the circulation and the action of the circulatory organs are automatic, and do not need special attention or special exercise. If we eat plenty of food these organs will get their full supply of blood. When we exercise our muscles the heart is exercised at the same time. All that we have to do in the care of these organs is to avoid any practices which injure them or their function. We must never subject them to overwork, and we must avoid taking into the system all substances which interfere with their action and health, as alcohol or tobacco.

Overwork. The heart is a muscle, and becomes exhausted by excessive exercise. The more work we do, whether with the muscles or the brain or the digestive organs, the more work the heart has to do. If we do too much, the heart may give out, and then all the organs suffer, since it is to the work of the heart that they owe their constant supply of nutriment.

Men in running races or in rowing not infrequently overtax the heart by keeping up too long. A heart once worked to the point of giving out may never be sound again.

The blood vessels also suffer from such strain. The walls of the veins may give way with the extra pressure and become *varicose.*

Taking cold. Undue exposure may give rise to an affection of the circulation known as taking cold. Sudden or prolonged exposure to cold contracts the peripheral vessels, i.e., those near the surface, and thus causes an accumulation or congestion of the blood in the interior parts of the body. This congestion in the membrane of the nose or air passages may cause inflammation or a tendency to inflammation, and, as a result, we have, with perhaps some irritation from without, a cold in the head (a coryza), or in the chest (a bronchitis).[1] The same cause may give rise to an inflammation of the intestines and diarrhea, or an inflammation of the lungs or of the pleural membranes (a pleurisy). Such conditions should be guarded against by avoiding sudden exposure. People should not go from a hot room into the cold air without extra clothing. At the same time a man should not become too dependent upon coats and mufflers, else he will catch cold whenever he leaves them off. The best plan is to keep the house cool, sleep with open windows,

[1] Certain of the affections of the air passages which we call colds are undoubtedly due to infections by microörganisms, and not merely to congestion of the parts. But susceptibility to these infections is increased by these congestions.

take a cold morning bath, and keep warm when out by walking briskly. In this way one becomes hardened to cold.

Hemorrhage. When a blood vessel is injured or cut, we have a flow of blood known as a hemorrhage (Greek *haima*, " blood," and *regnumi*, " I burst forth "). Where the wound is slight the flow will cease of itself, the openings of the vessels being closed by the clotting of the blood. This clotting is rapid in the blood of healthy persons. It is less rapid and complete in the blood of poorly fed people or people who drink much alcoholic liquors.

Where the cut is deep or a large vessel is severed, the flow prevents clotting. In such cases pressure must be applied to the vessel above the wound. If the cut is in a limb a handkerchief should be bound or twisted tightly about the limb,—above the cut if the bleeding vessel is an artery, below if a vein,—and the patient should be brought to a physician. All cuts should be scrubbed with water which has been boiled, to prevent the setting up of inflammation there. The air and the soil are filled with minute bodies known as bacteria, which get into these wounds and irritate them, if the lesions are not carefully cleaned.

Fainting occurs when the heart fails to pump the blood into the head. Such a condition may occur as a result of nervous shock which inhibits the action of the heart temporarily. When fainting occurs, the patient should be placed with the head low, when the blood will soon return to the brain.[1]

The blood corpuscles carry the oxygen to the tissues.

[1] The custom of giving a person who is fainting a few sips of cold water is based upon the fact that sipping water quickens the circulation, while ordinary drinking does not. During the act of sipping the action of the nerve which slows the beating of the heart is inhibited, and, as a consequence, that organ contracts much more rapidly, and the circulation in various parts of the body is increased. A child gets this same stimulation by sucking. Thus, when a child sucks its thumb after being scolded, it is getting itself cheered up by the increased circulatory activity induced—unconsciously, of course.

This they do by means of the hemoglobin which they contain.

One constituent of this substance is *iron*. We must be sure to have a supply of iron in the food, else the blood will suffer, and through this all the tissues will fail of their full supply of oxygen.

People who do not get sufficient food or the right kind of food suffer from a lack of corpuscles in the blood or a lack of iron in the corpuscles. This condition is called *anœmia* (Greek *a*, "without," and *haima*, "blood"). The condition may be due to overwork or impure air as well as poor food, as in these conditions the blood seems to be unable to gain sustenance from the food. In treating anæmia the endeavor should be to administer the iron in food rather than in medicines.[1]

The vitality of the body is directly dependent upon the purity and richness of the blood, and the capacity of the heart to keep this supply in active circulation throughout the parts. People whose blood is lacking in iron, or who have poisonous substances contained in the blood, are not strong and have diminished power to resist disease.[2] Where the heart is weak the blood tends to stagnate in parts. It fails of sufficient aëration and becomes impure. The parts cannot get the food which they need, and do not repair actively.

Germicidal power of blood. The blood of healthy individuals possesses a certain power to kill or make inactive

[1] The ordinary diet contains a sufficient supply of iron for health. Some foods contain much more than others. Thus, milk, rice, potatoes, bread, and cereals contain small amounts. The following, which are given in the order of their richness in iron, are the leading iron-containing foods: spinach, asparagus, cabbage (outer leaf), beef, mutton, lamb, dandelions, apples, almonds, hazelnuts, lentils, beans, carrots.

[2] Reports from the war between the Turks and the Greeks inform us that among the former the wounded recovered from the effects of severe injuries most marvelously. What is the reason for this? One reason is the fact that the Turks are compelled by their religion to abstain from alcoholic drinks. This gives them a great advantage, for their blood is pure. — Journal of Hygiene, 1897.

the germs of disease—a *germicidal* (Latin *cædo*, "I kill"—"germ-killing") power. Thus, in every open wound, and even when we eat and drink, a certain number of harmful bacteria probably get into the blood. But the germicidal power therein destroys them (and no abscess in the wound or no disease of the body results). Where these germs are in large numbers, however, the blood may fail to resist them, especially where the blood is poor, or the circulation inactive.

Leucocytosis (Greek *leukos*, "white," *kutos*, "cell," and suffix *osis*, "morbid state") **and phagocytosis** (Greek *phagein*, "to devour," and *kutos*, "cell"). This germicidal power of the blood *is believed by some to rest in part* in the white corpuscles. When a tissue is wounded or bacteria lodge anywhere, these little scavengers, the leucocytes, can be seen collecting to the point in great numbers. Some of the bacteria they eat up bodily. Others are killed probably by substances which come from the corpuscles. If these little soldiers, plus the germicidal power of the serum, are strong enough, they stop or drive back the invading enemy at the very outset. Then other cells appear which build up a tissue wall against further advance. If the enemy are too many, however, the invasion goes on into the body, and the person contracts disease.

Alcohol, when brought to act directly upon the heart, lessens the force of the muscular contractions. Its action when brought to the heart through the general circulation cannot be so perfectly studied. There can be no doubt, however, that alcohol when taken into the system may cause disorder of the heart's function and even disease of its tissue.

The common effect of alcohol drinking, whether developed by the action of the substance upon the central nerve centers of the heart or upon the heart muscle itself, is to increase the rapidity and diminish the force of the heart's

action, so that the heart runs itself out like a mettlesome horse who is given the rein.[1]

A heart thus disordered in its action cannot endure so much strain as a sound heart. It will give out more easily with exertion or disease. It is a well-known fact among physicians that the heart of a patient who is addicted to the use of alcohol is much less able to withstand the extra strain imposed upon it by the existence of some severe disease, as pneumonia, than the average heart.

Prolonged use of alcohol is very likely to cause a diseased condition of the heart, known as fatty degeneration.

The use of alcohol appears to be an element in causing a change in the linings of the blood vessels, known as *sclerosis* (Greek *skleros*, "hard"), which makes them hard and stiff and less able to do their part in the circulation. The firm elastic and muscular tissues are replaced by less strong connective tissue. This change is frequently followed by a softening of the whole wall of the vessels, especially of the aorta and large arteries, known as *atheroma* (Greek *athera*, "gruel"). These changes cause weakening of the walls in places, where the pressure of the blood may force the wall out into a thin-walled pouch, or *aneurism* (Greek *aneurunein*, "to dilate"). These aneurisms are very serious affairs. They frequently burst and cause death of the individual.

The dilation of the superficial vessels of the body caused by alcohol often becomes permanent with the constant use

[1] Even what is called moderate drinking has a much greater share than is generally supposed, not only in greatly increasing heart diseases in cases where they already exist, but also in inducing their development in the constitutionally and hereditarily predisposed to become affected by them. . . . Just as it happens that the dealers in horses ("runners out"), whose hearts are called upon to make oft-repeated and sudden exertions, are prone to become the victims of heart disease, in like manner the oft-repeated sudden spurts of cardiac activity induced by the frequent indulgence in small quantities of alcohol lead, for precisely similar reasons, to equally deleterious consequences in persons already affected by heart derangement. — George Harley, M.D., F.R.S., London.

of liquor. We are all familiar with the red-streaked appearance of the face and nose which is often thus caused in drinkers.

These various changes in the vessels which may follow the use of alcoholic liquors make the man liable to the breaking or plugging of a vessel in his brain. This condition causes what is known as apoplexy, and is often the cause of sudden death.

Tobacco often produces derangement of the heart's action. Individuals who smoke, and especially boys, frequently suffer from rapid and irregular beating of the heart. They become easily exhausted. Their vessels become weakened and dilated. Smoking may bring on temporary failure of the heart's action, with fainting. Whether these effects are temporary or permanent, these organs and the whole system suffer from them, and their powers of resistance are lessened.[1] This condition of "tobacco heart," which is very common in boys who smoke, will keep them from success in athletic contests. It will keep them from gaining admission to the army. In the examinations for enlistment during the recent war with Spain, many of the young men who presented themselves were excluded owing to tobacco heart.

DEMONSTRATIONS AND EXPERIMENTS

1. An ox heart with a good "pipe" upon it, that is, with the large blood vessels cut at a distance from the heart, should be obtained from a butcher, and the anatomy of the organ studied. By cutting open the heart the four cavities, the valves, and the apertures may be made out.

2. Study the effect of muscular exertion upon the rate of the heart action, by counting the pulse beats before and after running upstairs.

[1] Dr. Laban Dennis, of the New Jersey State Board of Health, reporting upon the effects of tobacco smoking upon the heart, says that it sometimes produces "irregularity, palpitation, a feeling of oppression and faintness, with breathlessness and insupportable pain in the region of the heart, which sometimes extends to the muscles of the chest and left arm."

3. Many of the phenomena of the circulation can be studied by means of a common Davidson syringe, or a syringe bulb with a short rubber tube upon the suction end and a long tube (six to twelve feet) upon the delivery end. Fit the long tube at the end with a glass tube drawn out to a fine caliber at the tip (a medicine dropper), to represent the resistance offered by the small blood vessels to the blood flow. Then spread the tube upon the table and force water through it by alternate compression and expansion of the bulb.

The bulb represents the heart. At the suction end is a valve which allows the water to enter, but not to go out at that end, just like the tricuspid or mitral valves of the heart, so that when you compress it, all the water which has entered must flow on through the delivery end and the long tube.

Note that though the water is thrown into the long tube in an intermittent manner by the successive compressions of the bulb, it flows from the end of the tube in a steady stream (the effect of the elastic walls of the arteries accomplished here by the use of an elastic rubber tube with an obstacle at the end).

The same principle is applied in the fire engine, where the elastic air in the air chamber plays the part of the elastic walls of the arteries.

4. Attach a nonelastic tube (a glass tube) to the bulb by a short rubber tube. Note that here the flow will be intermittent, not continuous.

5. Compress the forearm for a short time.

Note how the veins of the hand become distended by this obstruction to their flow. Note also the little knots or swellings which appear in the course of the veins. These knots mark the locations of the valves of the veins.

6. The circulation of the blood and the appearance of the capillaries and the blood corpuscles can be studied in the web of a frog's foot or the tail of a tadpole placed under a microscope.

Note the corpuscles flowing along. Note the walls of the capillaries. Note the cells of the walls.

QUESTIONS

I. What are the three objects accomplished by the circulation of the blood and lymph? Of what organs does this circulatory system consist? Where does the heart lie? What is the pericardium? Describe the heart. For what are the valves of the heart useful? Of

what kind of tissue is the heart principally composed? What is the chief property of muscle tissue?

II. By what is the heart action controlled? In what manner does the heart act? What causes the beat of the heart? What are the heart sounds? Describe the passage of the blood through the heart. Describe the action of the valves.

III. What is the pulmonary artery? Where does the blood which is sent to the lungs go after it leaves the lungs? Where does the blood go when it leaves the left ventricle? From what veins does the right auricle collect the blood? The left auricle?

IV. What are the three classes of blood vessels? What is the aorta? Name and place some of the principal arteries. Name some of the large veins. What are the two subsidiary systems of circulation? What is the object of the pulmonary system? Of the portal system?

V. Describe the structure of the capillaries. If you cut the wall of an artery it will not collapse; why? How is it with a vein? Describe the lymphatics. What does the lymph which they carry contain? Where is it made up? What are lymphatic nodes?

VI. What is the thoracic duct? Describe the method of the circulation in the vessels. What are the factors in keeping up the blood pressure? Of what does the pulse serve as an evidence? What is the force which causes the flow of the blood? What are the valves in the veins for?

VII. What is meant by the vasomotor regulation of the circulation? Is there enough blood to fill full all the vessels in the body? What happens in the vessels of the head and muscles when digestion is going on? How can we exercise the heart?

VIII. What is anæmia? How can we guard against it? What is taking cold? Has the blood any power to kill bacteria?

IX. What is phagocytosis? Is the rapid beating of the heart which is caused by alcohol drinking good for it? What is tobacco heart? Suppose the semilunar valve of the heart to give way, what would happen to the blood which the heart forces into the aorta?

X. What is the connection between exposing the surface of the body to cold air and a cold upon the lungs or in the head?

CHAPTER IX

RESPIRATION AND THE RESPIRATORY SYSTEM

IN addition to food, the body has to be supplied with another substance, free oxygen. As we have explained, the body is kept going, like an engine, by the burning of the substances within it. Now, burning within the body or without is, as you know, a process of oxidation. In order that it may take place, there must be free oxygen present with which the substance to be burned may unite. In the furnaces the coal gets this oxygen from the air. In the body, likewise, the oxygen is obtained from the air. It is obtained by the process known as respiration, or breathing. The air is taken into the part of the body known as the lungs. Here the oxygen is separated from the air and carried by the blood about the body to the cells, which are the furnaces where the burning takes place, the seat of the true or internal respiration.

Respiration (Latin *re*, "again," and *spirare*, "to breathe") is accomplished by a set of organs known as the respiratory tract. This tract consists of the upper air passages, the mouth, nose, pharynx, larynx, trachea, and the lungs.

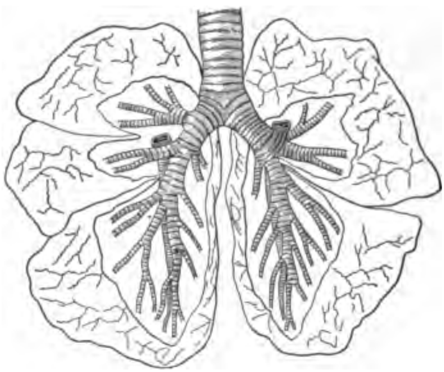
The mechanism of respiration is secured by the muscular action of the walls of the thorax, plus the natural air pressure.

Double object of respiration. The process of external respiration serves a double purpose. It accomplishes, first, the

importing of the free oxygen to the body; second, the exporting or elimination from the body of certain waste products of tissue combustion, the carbon dioxide and water.

I. THE RESPIRATORY TRACT

The chief organs of respiration are the *lungs*. On its way to and from the lungs, the air passes through the *upper air passages*. The air enters these passages by the *nose* or *mouth*. The cavity of the mouth has already been described.



Lungs.

The *nose* contains two cavities, separated by the nasal septum, the left and right nostrils. Each nasal cavity is partially divided into three chambers by the turbinate bones, which project into it. Behind, the nasal cavities open by the posterior nares into the pharynx.

The air in passing through the nose is warmed. It gains moisture from the nasal membranes, and it is freed from dust and germs by the hairs which lie in the anterior nares.

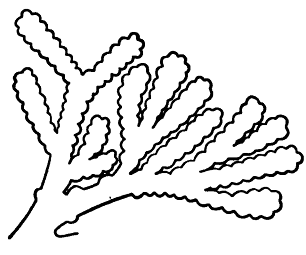
The *pharynx* is a funnel-shaped cavity which connects the nose and mouth cavities with the larynx and trachea. It has been described in the chapter upon the nutrition of the body.

The opening to the *larynx* is a narrow slit called the *glottis*. It is covered by a cartilaginous lid, the *epiglottis*

(Greek *epi*, "upon"—upon the glottis). This lid is open during respiration, but closed while food is passing the pharynx.

The *larynx* is a cavity between the pharynx and trachea. It is the seat of the organ of voice, and will be described in the chapter upon the voice.

The *trachea* (Greek *trachus*, "rough") extends from the larynx downward. Close to the lungs it divides into two tubes, the *bronchi* (Greek *bronchos*, "windpipe"), one for each lung. Each bronchus divides into numerous small bronchial tubes, which divide again into still finer ones. Each fine tube ends in a cluster of short blind tube branches. Each cluster of dilated tube ends is called an *infundibulum* (Latin, "funnel"). Each infundibulum is divided into several chambers by an infolding of its wall. Each chamber is called an *alveolus* (Latin *alveus*, "a hollow vessel").



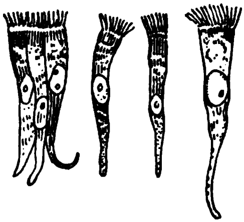
Lung infundibula.

In the lung are immense numbers of these infundibula with their alveoli, joined by connective tissue. The fine bronchial tubes, of which these infundibula are the dilated ends, conduct the air to the alveoli.

The lung may then be said to be made up of numerous branching tubes, the closed, dilated, and chambered ends of which are all bound together by connective tissue and inclosed in an elastic membrane, the *pleural* (Greek *pleura*, "side") *membrane*.[1]

[1] The lungs represent a contrivance for providing the body with as large a surface as possible for the absorption of the oxygen of the air. In small animals (insects) the surface of the body is so great in proportion to their bulk that the absorbent surface, provided by the external surface of the body, is sufficient for the needs of respiration, so that these animals need no special contrivance (no lungs) for this purpose. In higher animals extra surface is necessary. In fish this is provided by the gills. In air-breathing animals the lungs, with their thousands of little pits (alveoli), which greatly increase the surface included in a small space, are provided.

In *structure* the wall of the trachea consists of a connective tissue framework containing plates of cartilage connected together by muscular tissue. Internally the tube is lined by an epithelial membrane. The epithelium has as its surface layer columnar cells bearing each a short, thin process. These processes are called *cilia* (Latin *cilium*, "eyelash"). They are protoplasmic and are in constant motion, waving upward toward the mouth. By this action they drive any fluid which may collect in the trachea out toward the mouth. Similar cells exist in the larynx and nose, where they serve a similar purpose.



Ciliated cells.

The bronchial tubes have a structure similar to that of the trachea. The cartilage and muscle tissues are, however, of small amount here, and in the finer tubes they may be entirely absent.

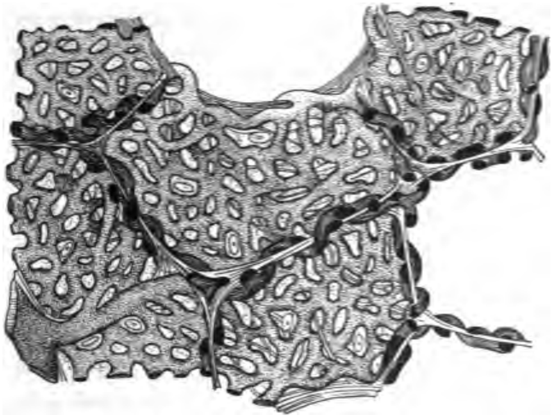
In the infundibula and alveoli chambers the walls consist of fine elastic connective tissue covered by an epithelial membrane continuous with that of the bronchial tubes, of which they are the termination. The cells of the membrane in the alveoli are flattened. In the connective tissue about the cells runs a network of capillary blood vessels.

As stated, the walls of the alveoli and the fine tubules contain much elastic tissue. As a result the lung is a very elastic organ. It can be distended by air to much over its natural size, but tends to return to this size and expel the air when the pressure is removed.

The pleural membrane. The elastic connective tissue membrane, the pleura, which incloses each lung, leaves the viscus at the root, and, folding upon itself, lines the walls of the thorax, in which the lungs are placed. Each lung is

thus surrounded by a closed sac in the same manner as is the heart.

The two free surfaces of this sac, which approximate each other, are covered with a serous membrane. This mem-



Lung tissue.

brane is moistened by a secretion from these cells. The surfaces of the sac thus slide easily over each other in the movements of respiration.

II. THE MECHANISM OF RESPIRATION

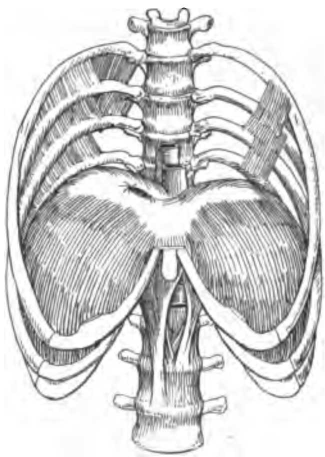
The function of respiration is regulated by the action of the walls of the thorax, under the control of the muscles which attach to or make up these walls.

The thorax is a conical cavity surrounded by a wall of bone, cartilage, and muscle. The walls consist of the vertebral column at the back, the ribs and the costal cartilages, with their fibrous tissue and muscles, at the side, the sternum in front, and the large muscle, the diaphragm, below.

Outside, this cavity is covered by muscle, fat, and skin. Inside, it is divided into a right and left cavity, each being lined by the serous membranes, the *pleura*.

The bones of the thorax are all so articulated that, by movements of its skeleton, the shape of the thorax can be changed, and its cavity enlarged or contracted.

Action of the diaphragm. The vertical enlargement of the thorax, the lengthening from top to bottom, is brought about by the large muscle called the diaphragm. This muscle forms the dome-shaped floor of the thorax. It consists of a central tendon, from which striate muscle fibers radiate in all directions. These fibers attach to the lower ribs, the sternum, and the vertebral column.



Diaphragm.

When they contract they pull the tendon down to a lower plane, thus enlarging the thoracic cavity at the expense of the abdominal below.

Action of the intercostal muscles. The increase in the size of the thorax from front to back is brought about by the raising of the rib arches and sternum upon the spine. This action is controlled by the *external intercostal* (Latin *inter*, "between," and *costa*, "rib") *muscles*, which run from rib to rib.

During rest the ribs which pass around from spine to sternum, the first seven, run downward. Each rib thus forms an arch or hoop, with its front lower than its back. The first arch at the top is the smallest. They then in-

crease in size until the lowest, the seventh, is reached. When the intercostal muscles contract, each arch is brought into the place of the smaller one above it, and the front point of the thorax, the sternum, lies farther from the spine in each plane than before. The thorax is therefore enlarged from front to back.

The raising of the thorax in this manner is accomplished by the contraction of each external intercostal muscle. The muscle from the first to the second rib contracts, and the second rib is pulled up, the first rib being held from coming down by ligaments and muscles above. The second muscle pulls on the third arch, and so on. These contractions occur simultaneously, so that the whole thorax is moved as one piece.

The *mechanism of inspiration* (Latin *in* and *spirare*, "to breathe") takes place in the following manner: The elastic lungs lie in the closed thorax. Through the air passages the air from without reaches them and presses upon the walls, just as it presses upon the body surface. As there is no pressure about the outer walls of the lungs except the pressure of the chest walls, this air pressure drives the elastic walls out until they everywhere fill the chest cavity and press against these chest walls. Thus when at rest the lungs are distended as much as the walls of the thorax will allow.

In inspiration the simultaneous contraction of the diaphragm and intercostal muscles makes the thoracic cavity longer and deeper, that is, considerably larger, so that the walls of the lungs, which were held in by the thoracic walls, expand still further under the air pressure from within, filling the larger cavity formed by the recession of these walls. In this way the lungs grow larger, and more air rushes in from without. The forces which govern inspiration are, then, muscular effort and atmospheric pressure.

Expiration (Latin *ex* and *spirare*, "to breathe out"). When the muscles have finished their contraction they relax, and as they do so, the walls tend to return to their old position. This decreases the size of the chest cavity again, and the walls of the lungs are pressed in by the incoming chest walls, the air being expelled through the air passages. This expiration in moderate breathing is due principally to the elasticity of the thoracic walls and lungs, which, when they are given a chance by the relaxation of the muscular tension, tend to return to their regular shape and position, driving out the air before them.

In forced respiration the action of inspiration is aided by the action of other muscles which pass from the thoracic skeleton to the spine. That of expiration is reinforced by the action of the abdominal muscles and the internal intercostal muscles, which lessen the regular size of the thoracic cavity. These muscles act in causing the short forcible act of expiration known as a cough.

Experiment. The action of the lungs in expanding under air pressure can be illustrated by a rubber bag placed in a jar from which the air can be exhausted. When the bag is opened it collapses, as the pressure of air is equal within and without, and the bag collapses by its natural elasticity. If the bag be placed in a closed jar with a tube connecting the bag with the outer air, and then the air in the vessel be exhausted, the bag will at once bulge out until it touches the walls of the jar. In this experiment the jar walls represent the thoracic walls, the bag the lungs.

III. THE GAS INTERCHANGE IN RESPIRATION

The object of the respiratory apparatus is to facilitate an exchange of gases between the body and the air.

The air is breathed in rich in oxygen. In the lungs it gives up some of its oxygen for use in the body, and takes up an equivalent of carbon dioxide waste from the body.

It is then breathed out again. The expired air thus differs in composition from the inspired air. It contains less oxygen and more carbon dioxide.

The quantity of air inhaled and exhaled in each respiration is about thirty cubic inches. The body therefore gets the benefit of the oxygen contained in this thirty cubic inches, and also of the carbon-dioxide-carrying capacity of this amount of air every time the action of breathing occurs (Experiments 2 and 3, pp. 194, 195).

The oxygen which the inspired air loses in the lungs is taken up by the blood. In return the air in the lungs takes up a certain amount of carbon dioxide gas from the blood.

This interchange of gases between the air in the lungs and the blood takes place through the walls of the lung alveoli and the blood capillaries. All about in the walls of the alveoli, in a network, lie these blood capillaries. They bring the venous blood, loaded with carbon dioxide waste, from the tissues to the alveoli walls. This gas waste is passed through the walls of the capillaries and of the alveoli as through a fine sieve, and is taken up by the air. At the same time the free oxygen of the lung air is passed through these walls and taken up by the blood, so that the dark venous blood, which comes to the lungs rich in carbon dioxide and poor in oxygen, goes away as a bright scarlet arterial blood, poor in carbon dioxide and rich in oxygen, and is thus distributed over the body.

The oxygen which passes into the blood is taken up there by the red corpuscles. These corpuscles contain a substance known as hemoglobin, which has a strong affinity for oxygen, combining with it to form a compound known as oxyhemoglobin.

In the circulation each corpuscle with its load of oxygen thus loosely combined is carried to the tissues throughout the body. Here this oxygen is given up again and used in

the tissues for combustion. It is this last step, this utilization of the free oxygen from the blood in the tissues, which is the real process of respiration, for the accomplishment of which all the other steps, the external respiration and circulation, are but a means.

IV. THE EXCRETION OF WATER BY THE LUNGS

In addition to serving as a means of gas interchange between the body and the air, the respiratory function serves other purposes. One of these is the removal of water from the body. The expired air always comes out moister, that is, richer in water, than the inspired air. A certain amount of water is removed from the blood in this way. This excessive moisture of the expired air can be observed upon a frosty day. The air upon issuing from the mouth looks like a cloud of steam. The water which is taken up by the lung air at the body temperature of 98.6° F. is deposited by condensation in the cold air outside (Experiment 4, p. 195).

V. THE ABDUCTION OF HEAT

Respiration also serves for the removal of a certain amount of heat from the body. The air taken into the lungs upon a day when the temperature is at 70° F. comes out with a temperature of 97° F. Thus just so much heat is removed from the body as there is difference in the inspired and expired air (Experiment 5, p. 195).

The *volume of the expired air* is greater than that of the inspired, since the air is expanded by the higher heat of the body and has also taken up water. Its gas volume, however, is less, as it has lost 5.4 volumes of oxygen and taken up only 4.3 volumes of carbon dioxide.

VI. HYGIENE OF RESPIRATION AND THE RESPIRATORY TRACT

The frame of the thorax and the muscles which control respiration are developed by vigorous out-of-door exercise, as running, rowing, and swimming. In inspiration the chest walls and the abdominal walls are driven outward. Tight clothing which interferes with this expansion, as tight corsets and tight belts, should be avoided.[1] Breathlessness or rapid breathing is much more marked after exercise in a woman who wears tight corsets than in one who does not.

The lining membranes of the air passages are easily irritated by the inhalation of fine, solid particles in the air, known as dust, or smoke. We should avoid working in atmospheres which are very dusty. We should keep our living rooms as free from dust as possible.[2]

Tobacco smokers are apt to contract a chronic relaxed

1 "Ample lung capacity is vital capital. This cannot be secured with the muscles of respiration bound down by tight clothing. In addition to giving them room for free play it is well to add to their capacity by special exercises in breathing. One of the simplest exercises is full, deep breathing. 'Draw in a long, deep breath, expanding the chest as fully as possible without straining either lungs or muscles. Retain the breath thus taken while you count ten; then as slowly as possible expel it.' Or, 'Stand erect with chin down, and rise on the toes as you inhale; hold the breath for a few moments, so that the air may act on the whole surface of the blood, nourishing it and at the same time taking up impure gases; then expel it forcefully and as completely as possible, coming down on the heels at the same time.'

"By such exercises the blood becomes saturated with oxygen, and the capillaries carry it to every part of the system, bathing every cell. . . . The lungs increase in elasticity, so that the chest expansion may be increased several inches, while the effect of these exercises reacts on every tissue of the body, producing a healthier tone and stimulating its growth."

2 The would-be neat but unwise housekeeper, after sweeping her carpeted floor, whisks the dust from her furniture with a feather duster, satisfied if she but transfers it from regions seen to those unseen. Not so the hygienic housekeeper. First of all, she reduces dust to a minimum by discarding carpets and living on bare floors with plenty of rugs which can be taken outdoors and beaten. She dusts her smooth floor with a soft or damp cloth, and so does not raise a fog as in sweeping a carpeted room. She dusts her bric-à-brac with a soft cloth, which she shakes frequently out of the window. She lets in volumes of fresh air and sunshine, and when she has finished her room it not only looks clean, but it feels clean, smells clean, and is clean.

condition of the membranes from this constant irritation, especially those who inhale the smoke.[1]

All influences which tend to congestion of the membrane of the lungs and air passages are to be avoided. Such influences, for instance, are undue exposure to cold and indulgence in alcohol. It has been explained in a preceding chapter how cold may cause inflammation of the lungs or air passages.

Alcohol, when taken frequently, keeps the membranes of the lungs and throat relaxed. The circulation in the dilated vessels is less active, and thus congestion and consequent inflammation are more apt to follow exposure in these cases than in healthy individuals. Such subjects suffer very frequently from pharyngitis and from bronchitis.[2]

Sore throats and *coughs* should be cared for at once, else the condition of the tissues may become chronic. When one has a cough he should not spit out what he raises upon the sidewalk or floor, but into appropriate vessels, as other people may contract the disease from the dried sputum lying or floating about. People with chronic coughs should live out of doors in dry country air.

Ventilation. The air of a room with people in it is constantly losing oxygen and accumulating carbon dioxide and other substances excreted in the expired air. Some of these

[1] Habitual smokers are notoriously liable to colds in the head and to bronchitis and other congestive affections of the air passages. On this subject Dr. J. F. Rumbold says: "The congestion occasioned by the action of tobacco on the mucous membrane of the superior portion of the respiratory tract resembles in many respects the congestion resulting from the effects of a cold. Some of these are transitory and some permanent. The local effects of tobacco on the mucous membrane of the superior portion of the respiratory tract causes a more permanent relaxation and congestion than any known agent." Tobacco depresses the system while it is producing its pleasurable sensation, and it prepares the mucous membrane to take on catarrhal inflammation from even slight exposure to cold.—British Medical Journal, 1880.

[2] Those who have injured themselves with alcohol show less power of resistance against influences unfavorable to health, and are carried off by diseases which other people of the same age pass through safely, especially in cases of inflammation of the lungs.— Birch-Hirschfeld.

excreted substances are poisonous, and if they are allowed to accumulate in any quantity will poison the people who breathe the air, causing headache, dullness, and exhaustion. So it is very important to prevent the accumulation of these products. To accomplish this prevention we must keep the room air constantly changing. This system of changing the air of a building is known as ventilation.

The carbon dioxide excreted by the lungs does not collect in amount sufficient to have a poisonous action, but the amount of it present serves as an index of the amount of poisonous impurities present. So by measuring the carbon dioxide in the air of a room we are able to tell whether the air is pure or impure. If the air contains two volumes carbon dioxide in ten thousand volumes air, we call it fresh. If it contains six volumes carbon dioxide it is impure. So we arrange our ventilation to keep the proportion of carbon dioxide in the air as much below six volumes as possible.

Ventilation is best secured by bringing the fresh air in high up, and allowing the mixed air to escape by fireplaces or other ventilators. The fresh air may be brought in warm by hot-air apparatus, so as to avoid drafts of cold air.

It is important that the air should contain a certain amount of water. Very dry air takes too much water from the membranes of the air passages, and causes a consequent irritation of the tissues. Stoves in a room are likely to dry the air too much. Hot-air flues or open fires are better means of providing heat.

The odor of the air is a guide to its condition. Wherever the air of a room smells close, ventilation should be applied.

The constant purification of the air is carried on by plants. These organisms break up the carbon dioxide which collects in the air, and take up the carbon, leaving the oxygen free for the air.

Not only is a continuous supply of oxygen essential to

life, but any diminution in the exchange of oxygen and carbon in the system lessens nerve sensibility and muscular force. Confinement in close rooms is probably, in cases, a predisposing cause of consumption, which numbers far more victims than any other one disease in our temperate climates. Probably a majority of all the families in the country live all winter shut up in close, heated rooms, with the life giving oxygen carefully shut out, and poisonous vapors as carefully shut in.

"Live as much as you can with open windows, wearing whatever extra clothing is necessary. If you cannot bear an open window, even with an extra coat and a rug over your knees, when you are sitting in a room, do the next best thing, which is to throw the windows wide open, and take some active exercise for a few minutes, while the air in the room is being swept out and fresh air coming in to take its place." Avoid chill, but at the same time avoid impure air. In a room where no means of ventilation are furnished, as is usually the case, there are various simple ways of keeping the air constantly changing without lowering the temperature too much or creating a draft. One is, where there is an outside door in the room, to fasten a chain upon it with a hook on the opposite side, over which the links of the chain may be thrown. The door may then be opened an almost imperceptible crack, or an inch, or half an inch, according to the weather. A screen can be set inside the door to shut off any draft, if there be any. Or the lower sash of a window may be raised a few inches and a piece of perforated zinc placed in the open space. The foul air will go out through the zinc and the fresh air come in between the sashes with an upward current, and the latter will thus become warmed before it circulates through the room.

Sleeping room ventilation is also an important matter.

These rooms should be large and well lighted, and some means devised for securing a constant change of air without direct draft during the night. In the morning the windows should be thrown wide open as soon as the room is vacated, the sheets and blankets should be taken off one by one, shaken, and spread out to air, and the room left for at least an hour with the air and sunlight pouring in before the bed is made up. Blankets that can be washed are the only suitable bed coverings; mattresses should be pulled apart, cleansed, and made up with new covers every few years. The furniture should be plain and simple, and such as can be kept free from dust.

Tonsils. There are certain parts, in structure like that of lymph nodes, present in the throat, known as tonsils. Where these are large they may interfere with respiration.

Adenoids (Greek *aden*, "a gland," and *eidos*, "like"). Some people have growths of tissue in the nasopharynx known as adenoids. Large tonsils or adenoids tend to obstruct the air passages and thus to interfere with respiration. The adenoids, obstructing the posterior nasal openings, tend to cause mouth breathing, which is not so good as nasal breathing. When a child breathes with the mouth open, adenoids should be suspected.[1] If large tonsils or adenoids are allowed to remain in children they may affect the development of the lungs and thorax. They make the middle ear more susceptible to disease by affecting its air supply through the Eustachian tube. They therefore should be removed early.

[1] People of all ages need to know that it is necessary to keep the mouth shut, for it was not intended for breathing purposes, the nose being essential to this purpose and having the advantage that it warms the air and strains from it irritating matters injurious to the lungs. Remember the mouth is exclusively needed as a port of entry for food and a port of exit for crystallized thought, the chief medium of communication between man and man. — Journal of the American Medical Association, November 20, 1897.

It is an excellent habit to rinse the mouth and throat every morning with warm water or salt and water.

Asphyxia. When the blood cannot get oxygen the person is said to be asphyxiated. Such a condition occurs where a person is smothered or suffocated by smoke or illuminating gas, or is drowned.

Drowning. A drowning person has lost the oxygen from his lungs and blood. The heart and lungs have therefore ceased to work, as neither circulation nor respiration can go on without free oxygen. To resuscitate a man who has been exposed to drowning we must first place him on his face, with his head low, to let the water run out from his lungs. Then apply warmth about him and start the respiration by artificial means.

Artificial respiration. The person is placed upon the back, with clothes removed. The arms are lifted straight above the head and then lowered again to the sides, pressing in the thorax. This motion should be made regularly about eighteen times a minute. Unless the patient has gone too far the respiration will return in time and the circulation start up.

DEMONSTRATIONS AND EXPERIMENTS

1. Each pupil should demonstrate the presence of the air cavities in his thorax by placing one hand flat upon his chest wall and striking the back of his fingers lightly with the midfingers of the other hand. A sound such as is obtained by striking the walls of a box or of any receptacle filled with air will be heard. Contrast this with the sound obtained by percussing (as above) the skull.

Note the movements of the abdomen and of the chest walls in respiration.

2. Repetition of Experiment 6, page 34.

Place some limewater in a bottle. Exhale for several minutes through a glass tube which enters this liquid. The limewater will become turbid owing to the carbon dioxide which comes into it from the air which you exhale. This carbon dioxide unites with the calcium of

the limewater to form a white substance, calcium carbonate, which, makes the limewater turbid.

3. Weigh out 8.7 ounces of charcoal. This represents the amount of carbon waste which the body gets rid of through the lungs daily in the form of carbon dioxide.

4. Breathe upon a mirror.

The moisture which condenses here comes from the exhaled air, which this demonstration shows to be charged with more moisture than the air without.

5. Place the hand before the mouth.

Note the warmth of the breath.

Hold a delicate thermometer in front of the mouth. The mercury, which has perhaps stood at 70° (the room temperature), will mount rapidly, showing evidence of the heat which comes out with each exhalation.

6. The principle of the mechanism of respiration can be illustrated by the following apparatus:

Remove the bottom from a bottle. Stretch a thin sheet of rubber tightly across the opening to cover it entirely, and bind it in place.

Attach a stick to the center of this rubber sheet.

Take a cork with two holes in it fitted to the top of the bottle. Through one hole run a glass tube with a collapsed toy balloon attached to its lower end. Through the other hole run a glass tube with a rubber tube attached to its upper end. On the rubber tube place a pinch cock. Insert the cork tightly so that the balloon lies within the bottle.

Draw some of the air from the bottle by sucking through the rubber tube. This exhaustion of the air inside will cause the rubber sheet to arch upward. Close the rubber tube by the pinch cock.

Then draw down the rubber sheet by the stick. As it descends the balloon will begin to fill out (expand).

The balloon here represents the lungs, the rubber sheet the diaphragm.

7. To demonstrate the circulation of air in a room.

Pour some concentrated hydrochloric acid into an evaporating dish. (Be careful not to inhale the fumes.)

Pour some ammonic hydrate into another dish.

Bring the dishes near together.

Note the fumes that form. Note the course which they pursue.

Try this experiment in several parts of the room to study the direction of the air currents therein.

Record air pressure in the mouth—its strength and direction (upon manometer)—in quiet inspiration; in expiration; in forced inspiration; in forced expiration.

QUESTIONS

I. For what purpose does the body need free oxygen? By what process is it obtained? What other useful purpose is accomplished by external respiration? Describe the respiratory tract. What happens to the air in the nose? What is the use of the epiglottis? In what do the air passages end?

II. Describe the lungs. What is the function of the ciliated cells of the trachea? What is the use of the cartilage in the tracheal walls? Of the elastic tissue in the walls of the finer bronchi? Describe the mechanism of respiration. What is the great muscle of respiration?

III. Describe the structure of the thorax, and show how the size may be increased by muscular action. What are the physical forces which govern inspiration? Expiration? Forced expiration? How is the air changed in the lungs? In composition? In moisture? In temperature? Of what is air composed? What does the blood obtain from the air in the lungs? What does this air obtain from the blood? If the lungs were shut off from the circulation what color would the blood in the arteries assume?

IV. How does the blood carry the oxygen? Where is the seat of the real body respiration? How do we get rid of water by breathing? How do we get rid of heat? Can you ever see the water which comes out in the air from the lungs?

V. What is apt to be the result of smoking upon the tissues of the air passages? What would happen to the air of a room full of people if it were not constantly renewed from without? What are the best methods of ventilating a room? To what agency do we owe the purification of the air in natural conditions? How should sleeping rooms be ventilated?

CHAPTER X

WASTE AND EXCRETION—THE EXCRETORY ORGANS

WE have seen that the activity of the living organism is kept up by energy which is supplied by the oxidation of the living tissues. As a result of this combustion certain waste substances are formed in the body, just as waste substances, ashes and smoke, are formed when coal is burned. These waste substances are low chemical compounds of the elements which make up the tissues, carbon, oxygen, hydrogen, nitrogen, and so forth. They are principally carbon dioxide (CO_2), water (H_2O), and nitrogen. The nitrogen, before excretion, is formed in the body into a compound known as urea, and excreted as such.

The waste products have to be disposed of. Just as the ashes of a furnace must be taken out, or they clog the furnace fires, the waste substances must be removed from the tissues and the body, or they would clog the burning in the tissues. To provide for the disposal of these substances is the work of certain organs called *excretory* (Latin *ex*, "from," and *screo*, "I hawk") *organs*. They are principally the lungs, the kidneys, and the skin.

Excretion of waste. The waste products are taken from the tissues by the lymph and blood. By the blood they are carried to the organs mentioned, and there separated from

the blood and passed out of the body. The process of the elimination of waste products is called *excretion.*

Of the waste products, the carbon dioxide is removed from the body by the lungs; the water by the lungs, skin, and kidneys; the nitrogen waste, the urea, by the kidneys.

I. EXCRETION BY THE LUNGS

The process of the elimination of the carbon dioxide and water by the lungs in the function of respiration has been described in the preceding chapter.

II. EXCRETION BY THE KIDNEYS

The kidneys lie at the back of the abdominal cavity, one on each side of the lumbar vertebræ. Each kidney is a dark-red organ, about four inches long by two and a half broad, and one inch thick. The inner border of each is concave, the outer convex. Into this concave notch, or *hilus* (Latin, "a trifle"), of the inner border the artery of the kidney enters, and from it the vein leaves. From this same hilus the *ureter*, or discharge vessel of the kidney, proceeds.

Section of a kidney.

Structure of the kidney. The kidney is a gland of a very complex structure. If we open a kidney we see that the cut surface appears to consist of two parts, a cortical (Latin *cortex*, "bark") part and a medullary (Latin *medulla*, "marrow"). The medullary portion appears to be made up of a number of conical

portions, the *pyramids*, which protrude into a sacculated portion, the *pelvis* (Latin, "basin") of the kidney. From this pelvis runs the ureter, or discharge pipe. In minute structure the kidney consists of very small tubes lined with epithelial cells, about which are arranged, in a network, blood vessels and lymphatics. The whole mass is held together by connective tissue and surrounded by a firm capsule (Experiment 3, p. 212).

The arteries from the main artery at the hilus run among the tubes and ramify into fine branches in the cortex. These branches end in fine clusters of capillaries known as *glomeruli*. From each of these clusters a vein issues. Each cluster of capillaries, or *glomerulus* (Latin *glomus*, "a ball of cotton"), is surrounded by the closed, dilated end of a *tubule* ("small tube"). The whole structure, the cluster of vessels projecting into the closed end of a tubule, is known as a *Malpighian* (after Malpighi, who first described it) *capsule*.

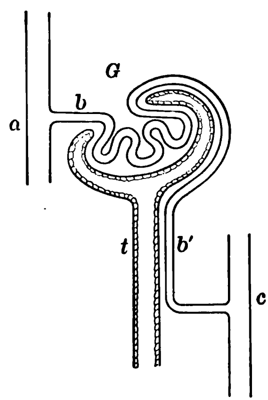
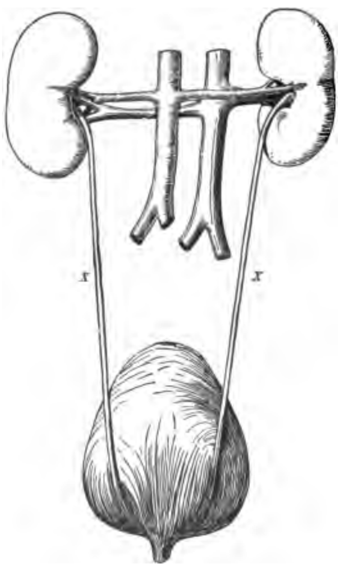


Diagram of kidney circulation, showing a glomerulus and tubule.

a, artery bringing blood to part; *b*, capillary bringing blood to glomerulus; *b′*, vessel continuing with blood to tubule; *c*, vein; *t*, tubule; *G*, Malpighian capsule and glomerulus.

The wall of a tubule consists of a single layer of epithelial cells, mostly cubical in shape. The tubule begins at its closed, dilated end about a glomerulus. From here it proceeds by a tortuous course to the medulla, joining with other tubules and forming straight tubes which run parallel in the medulla and end at the pelvis. The water and some of the waste substances of the blood running in the glomerulus capillaries are separated from the interior of the tubule by the walls of the capillaries and the wall of

epithelial cells which lines the closed end of the tubule surrounding the glomerulus. Through these thin layers of cells the waste substances pass into the tubules.



The kidneys and bladder.
x, *x*, ureters.

Below the capsules the blood capillaries run in a network about the tubules, and from these lower capillaries the *urea* is separated into the tubules, just as is the water above. Together these waste products are borne along the tubules to the pelvis of the kidney.

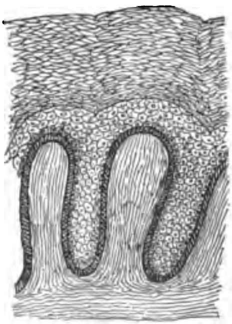
The separation of these products is due to the specific action of the living cells which line the tubule. These waste substances are taken from the blood, while other useful substances, as albumin, are left behind.

Urine. The amber-colored liquid which is thus formed by the separation of waste materials from the blood by the kidneys is called *urine.*

III. EXCRETION BY THE SKIN

The skin is made up of two layers. The outer layer, the *epidermis* (Greek *epi*, "upon," and *derma*, "skin") or cuticle, is formed of several strata of cells. The inner stratum consists of columnar cells, over this are several layers of round cells, and over these two strata are several layers of flattened cells, which, as you approach the surface, become mere scales. The outer stratum consists of dead cells which have

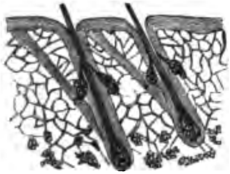
lost their nuclei and become cornified or hardened. It is called the horny layer. The scales of this layer are constantly wearing away and peel off with friction, while new cells are being constantly added from the inner layers. This outer layer may be separated from the inner, as in the case of a blister (Experiment 1, p. 212).



Section of skin of negro.

The deeper strata of the epidermis make up the *Malpighian layer*.

The deeper layer of the skin is called the *dermis*, or *corium*. It is composed of a network of connective tissue, containing white fibers and yellow elastic fibers. The surface is raised into numerous elevations called *papillæ* (Latin, "nipples"). Some of these papillæ contain clusters of blood vessels; others contain the nerve organs of the sense of touch. This layer of skin is well supplied with blood vessels and nerves. A cut through the epidermis alone causes no bleeding. A cut into the dermis bleeds. The dermis rests upon the deeper tissues of the body, muscle and bone. It is separated from these by a loose tissue known as *subcutaneous* (Latin *sub*, "beneath," and *cutis*, "skin") *tissue.* It is in this tissue that much of the fat in fat people lies.

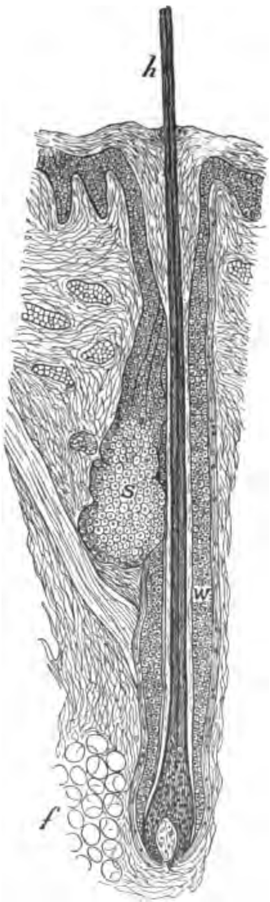


Section of the skin showing the roots of the hairs and the sebaceous glands.

The dermis contains several special structures. These are the hairs, the sebaceous glands, the sweat glands.

The hair. Hairs are found all over the body surface except on the palm and sole. Upon the head the hairs grow long. Over most of the body they are short and very fine.

Each hair is made up of a column of flat cells, like those in the epidermis, with a central shaft. It lies in a pit lined with epidermal cells and situated in a special papilla of the dermis. This pit is the hair *follicle* (Latin *follis*, "a bag"—a little bag). The cells at the base of the follicle form the *root* of the hair. The hair grows by the multiplication of these cells. As new cells form the older ones are thrust upward and become cornified, forming the column of the hair.



Hair and hair follicle, with sebaceous gland entering follicle.

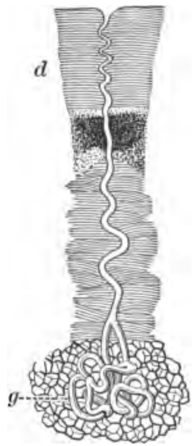
h, hair; *s*, sebaceous gland; *w*, wall of follicle; *f*, fat tissue.

The *sebaceous* (Latin *sebum*, "suet") *glands* are small racemose glands consisting of clusters of cell-lined tubes with a duct opening into the follicle of a hair. The secretion of these glands is of a fatty nature; it keeps the skin soft.

The principal structures of the skin which carry on excretion are the *sweat glands*. Each sweat gland is a blind tube, the inner end of which lies coiled in a knot in the dermis. These tubes, starting from this coil, run in a corkscrew course through the epidermis and open upon the surface. The openings are called the *pores*. Each coil and tube is lined with a single layer of cubical cells. About the coil run blood vessels. From the blood in these vessels the glands separate

certain substances, as water, inorganic salts, and organic matter, which are discharged as an alkaline fluid called *sweat.*

Perspiration (Latin *per*, "through," and *spirare*, "to breathe"). This elimination of sweat is known as perspiration. The total amount of sweat in twenty-four hours is from twenty-five to seventy ounces (one and a half to four pints). Ninety-nine per cent of the sweat is water. The function of perspiration removes principally heat and water from the body.



Sweat gland, with duct.
d, duct; *g*, gland.

Elimination of heat. The perspiration eliminated to the surface of the body evaporates, and the water thus turns from a liquid to a vapor. In this change heat is taken up from the body by the water in becoming a vapor, and removed with it into the air. In ordinary conditions the amount of perspiration is comparatively small and evaporates from the pores, so that it does not appear upon the body. Such perspiration is called *insensible*[1] (Latin *in*, "not," and *sentire*, "to perceive"). In hot weather or after exertion the sweat pours out more rapidly than it can be evaporated, and collects in a perceptible moist layer or in drops upon the body surface. This is called *sensible* perspiration. By this large flow and evaporation of sweat much heat is removed from the body. The increase of sweat is assisted in these conditions by dilatation of the peripheral vessels and increased flow of blood to that part. Likewise in cold weather, when it is desirable to lessen the elimination of heat as much as possible, the vessels are constricted and

[1] The evidence that insensible perspiration is going on continuously can be obtained by placing a rubber cot upon the finger upon going to bed. In the morning, upon removing the cot, the finger will be found to be moist and swollen with the perspiration which has been prevented from evaporation.

the flow of blood to the skin lessened. The secretion rises with this increased flow, but is not absolutely dependent upon it. It is regulated by nerve control.

The nails. The nails consist of epidermis of the outer layer of horny cells formed into a plate. The nail lies in a bed of corium, called its *matrix* (Latin *mater*, "mother"). This portion is very vascular. Here new epidermal cells form, by which the outer cells are pushed out and thus the nail grows.

IV. EXCRETION BY THE INTESTINES

The egesta from the intestinal tract, the fæces, consist of the excretions of the liver and other glands, of the waste substances separated from the walls of the alimentary tract during digestion, and of the undigested elements of the food.

V. HYGIENE OF EXCRETION AND THE EXCRETORY ORGANS

The removal of waste is absolutely essential to the continuance of health. If the waste products of muscular action, digestive action, brain action, are allowed to accumulate in the body, they will interfere with the health and function not only of these special organs, but of the whole body. We must do all that we can to accelerate excretion.

The attention must be directed first to keeping up a good circulation, since it is by circulation that the waste products are carried from the tissues to the excretory organs. The circulation is kept active by exercise and baths. In indolent people the circulation is apt to become sluggish, and the accumulation of poisonous waste resulting frequently increases the indolence. It causes dullness, drowsiness, and headache. The muscles become easily exhausted. The nu-

trition of the tissues becomes unhealthy. Such people not only do not feel well, but they are less able to resist disease.

In the second place, we must keep the excretory organs in good condition. We must drink plenty of water to keep the kidneys flushed and to prevent concentration of the urine. A concentrated urine contains much solid matter in proportion to its water. It may irritate the renal tissues, its passage causing inflammation. It may tend to deposit its solids in the course of its passage, giving rise to the condition known as *gravel.*

All substances which tend to irritate the kidneys should be avoided.

People who keep their kidneys under constant irritation by indulgence in alcohol are apt to develop a chronic disease of the kidneys, chronic nephritis (Greek *nephron*, "kidney").

When the kidneys give out, many waste products collect in the body and poison the organism. This condition is known as *uræmia.*

The *care of the skin* consists in proper bathing and proper clothing. The excretion of the skin, the perspiration, in evaporation leaves its solid matters crusted on the skin. The sebaceous excretions tend to collect there. Dirt also gets on from without. All these substances tend to obstruct the pores and thus to interfere with the excretory action of the skin.[2]

Baths. The skin should be bathed daily. A cold sponge bath is preferable for those with whom it agrees. This bath clears away the deposits and causes a contraction of the pe-

[1] Water is the vehicle in which are carried in solution the ingredients of tissue waste which the system is trying to get rid of. The flow of water through the kidneys to the bladder furnishes a current in which to carry off the dissolved detritus; therefore the drinking of a physiological amount of water is a benefit and not a detriment to the kidneys.

[2] Exercise in the open air improves the appearance of the skin and is necessary to all who would have fine complexions. And yet exercise and bathing are not all. If the diet and digestion are bad the complexion will suffer. Fruits help to keep the system clean internally and to prevent the accumulation of waste matter which gives the skin an unwholesome appearance.

ripheral (surface) blood vessels, which is followed by a dilatation and an increased flow of blood to the surface. In this way the circulation is stimulated. Those who do not react, that is, feel a healthy glow, after a cold bath would better use a warm one. Too long exposure to a cold bath will weaken instead of brace the system. Soap should be used upon the hands and the parts exposed to external dirt. A soap bath is not necessary oftener than once a week. The scalp should be washed every two weeks. Do not bathe while perspiring freely.

Clothing. The skin should be kept at as even a temperature as possible. The best clothing to wear next the skin should therefore be made of a substance which is a poor conductor, as wool. This will keep the body heat in. When the temperature without is high, as in summer, we can use cotton clothing, which conducts more readily. One must be careful about undue exposure in changing the thickness of the clothing.[1]

Regularity of the bowels. The eliminations from the intestines (fæces) consist principally of waste tissue substances and the undigested residue of food. If these substances remain stored up in the intestines they poison the system and are a menace to health and comfort. In a large proportion of people who feel run down, suffer from headache and nervous disorders, the trouble is secondary to constipation.

The bowels should move daily. Nature perfects most processes by forming habits in their regard. The bowels should be made accustomed to move at a regular time daily, and they will soon acquire this habit.

[1] People, and especially children, should dress according to the weather, and not according to the season. In winter woolen night garments are better than cotton, which may cause too sudden a change in the body temperature. Mackintoshes should not be worn without some other wrap underneath, as they hold in the heat and keep the body warm in some places and expose it in others, especially about the arms, which are sensitive. In this way they may predispose to pneumonia. "Mackintoshes and pneumonia are twins," one physician declares.

Much constipation is due to improper dieting, improper modes of dress, and improper habits in regard to exercise. Plenty of bread, green vegetables, and fruits must be included in the diet list. Where a tendency to constipation arises it should be counteracted by the addition of more fruit and vegetables to the diet, especially such fruits as prunes, figs, tamarinds, and berries. Graham bread is preferable to white in such cases. A glass of warm water upon rising in the morning may prove helpful in this regard.

Indolent habits tend to promote sluggishness of the bowels. Horseback riding or running and rowing are excellent means of counteracting this sluggishness when it exists.

Tight belts and clothing which binds about the waist tend to produce sluggishness of the bowels. Habits of regularity, diet, exercise, should all be tried before medicines are resorted to for the relief of constipation. When once a person begins using drugs to combat conditions which are the result of improper habits and negligence, he is giving hostages to health. The drug habit once fastened upon his shoulders will stay there like Sindbad's "Old Man of the Sea." The right method is to discontinue the evil habits.

The disposal of body waste. The proper disposal of the excretions, especially of the urine and fæces, is a matter of great importance. If not disposed of in the proper way these excretions will prove a source of contamination and disease to the community.

Many diseases are essentially filth diseases, and their spreading, even their occurrence, can be controlled by proper sanitary regulations. Such a disease is yellow fever, which has played such havoc in Cuba. Several of the infectious diseases common with us, as typhoid fever, are transmitted through the excretions, and their existence can be absolutely stamped out in communities by proper care. The

bacteria which are the cause of typhoid fever are present in great numbers in the excreta of persons suffering with this disease, and if these excreta are not disinfected, but are thrown into ordinary earth closets or into those which empty into streams and rivers, a widespread epidemic of this disease may arise from a single case. The people living downstream may contract the disease by drinking the water.[1] The drainage from the earth closet carrying the disease germs may sink into a well. The water of this well may be used to wash milk cans by some farmer who supplies a village with milk, and the germs thus get into the cans and into the milk, and thus an epidemic of the disease run through the families who buy the milk. Typhoid fever may be also spread by means of flies, as occurred in some of our camps during the late war with Spain. The bacteria are so minute that a single fly could carry away upon its foot as many as there are shingles upon the roof of a house.[2]

All excreta from people suffering with contagious diseases should be thoroughly disinfected by chlorinated lime or some other disinfectant, or burned or buried, and all excreta, whether in health or illness, should be disposed of in proper closets where no flies can obtain access, and where they

[1] The mistaken notion that a running stream will rid itself of noxious substances should no longer be entertained where life and health depend upon absolutely pure drinking water. — Seventeenth Annual Report of the New York State Board of Health, 1897.

The same report says also that official approval should be withheld "from any proposed sewerage system which does not provide for other disposal [of sewage] than into any stream which, in any part of its course, may be used for drinking purposes."

[2] It has been demonstrated that the germs of typhoid fever, cholera dysentery, and camp diarrhea are present in the discharges of those suffering from these diseases, and the propagation of these infectious camp diseases results to a large extent from failure to properly dispose of excreta. No doubt typhoid fever, camp diarrhea, and probably yellow fever are frequently communicated to soldiers in camp through the agency of flies, which swarm about fecal matter and filth of all kinds deposited upon the ground or in shallow pits, and directly convey infectious material, attached to their feet or contained in their excreta, to the food which is exposed while being prepared at the company kitchens, or while being served at the mess tent. — Sanitary Recommendations of Surgeon-General Sternberg.

cannot drain into wells or running streams that are used for drinking water.

In cities and towns with proper sanitary regulations all wastes are carried away by sewers to proper places of disposal. In the country and in villages where such an arrangement does not exist, the greatest care should be observed in the disposal of excretory matter, that it may not contaminate the air or the water supplies. Cesspools should be abolished. Earth closets should be used, into which should be thrown daily a quantity of dry earth and the whole frequently removed.[1]

House sweepings and kitchen refuse should be burned, and all slop water containing matter capable of causing disease should be disinfected with chlorinated lime.

VI. THE BODY HEAT

The human body is nearly always warmer than the things about it. This is due to the fact that heat is constantly being produced in the body. This production of heat comes from the combustion of the tissues and their stores of food. When energy is liberated by the breaking down of any substance, as in the burning of the tissue of man or the wood tissue of a tree, this energy may take several forms. When the wood is burned outside the body the energy liberated takes the forms of heat and light. When the tissues are burned in the body the energy liberated takes the forms of heat and work. From four fifths to five sixths of the energy liberated in the body goes to heat.

[1] The contents of such closets are sometimes used on land for fertilizers. This should never be done where green vegetables for human consumption are to be raised, as disease germs still retaining their vitality have been found thus disseminated on the vegetables so raised. Instinct teaches animals like the cow and horse to shun the herbage, however luxuriant, that grows about their own excretions. Man's intelligence ought to read in this nature's warning against retaking into his system the wastes that have been thrown out for decomposition.

This heat is being produced continuously, since the tissues are continuously burning. The burning, and consequently the production of heat, is more active during marked activity of the organs, as with muscular exercise or excessive mental work; but it is going on all the time, as the heart is beating and the blood circulating and the cells secreting. This heat is distributed over the body by the blood. It is removed from the body by all the excretions, as the expired air, the evaporation of the sweat, the urine, and also by simple conduction into the air about.

Regulation of the body temperature. By a certain regulation of the mechanism of the body, the production and elimination of heat are always equalized, so that the temperature of the body remains constant. This is 98.6° F., taken in the mouth. When more heat is produced, as by active exercise, the peripheral circulation and the perspiration are increased, and thus more heat is removed from the body by conduction and evaporation. When the surrounding air is very hot the production of heat in the body is lessened and the perspiration and evaporation are very profuse, so that the body does not get any hotter. When the air is cold the production of heat is increased and the peripheral vessels are contracted, so that less heat goes to the surface and thus less is conducted away, and the internal organs of the body become no colder.

Sources of body heat. The heat energy comes from the tissues, and these from the food; so that in an indirect way the heat is produced from the food. When more work is done, more energy is needed and more liberated; so more tissue is burned, and therefore more food must be taken to keep up the equilibrium. If we burn a food outside the body and estimate its energy in heat, we find that this is the same as the energy which the food produces in the body in heat plus work, provided always the food can be digested and has

no poisonous action. Certain foods, as the fats, have great heat-producing energy stored up, and where such energy is required, as in cold weather, such foods are very useful.

A comparison of the effect upon the body heat of the consumption of a given amount of a regular food substance, as fat or carbohydrate, and of the same amount of alcohol, is interesting, as it illustrates the difference in the action of a food and a poison upon an important body function.

Fat, alcohol, and sugar are all hydrocarbons. When they are burned or oxidized outside of the body they give rise to a certain amount of heat. Fat causes most heat, alcohol next, and sugar least. It might be argued, therefore, that the body could get heat from them in this order. When, however, we feed a person upon each of these substances and allow them to burn in the body, we find that alcohol causes a loss of body heat, so that the body is colder, not warmer, while fat or sugar causes it to keep up its normal heat. The alcohol contains more heat, as we have seen, than the carbohydrate; but its poisonous action upon the system is such that the body fails to get the benefit of the heat which is in it.

Effect of alcohol on body temperature. This maintenance of the body heat is necessary for the health of the body. It fortifies us against cold. So that, if we were going out into the cold, the worst thing which we could do would be to take any alcoholic liquor, for we should be throwing away some of the heat which the body would need to resist the cold. Many people do not know this. They think that because the alcohol makes them feel warm the body is therefore warmer. But travelers in frigid climates have learned the fallacy of this idea by hard experience.

This action of alcohol in reducing the body heat and the power of resistance against cold is well illustrated by an adventure which is recorded of several travelers who were

caught in a snowstorm in the Sierra Nevada Mountains. These travelers lay down to sleep exposed to very great cold. Several took a large amount of alcohol. It made them feel warm and comfortable, and they fell asleep. Others took a little alcohol. Others took none, but went to sleep feeling chilly. In the morning the men who took much alcohol were frozen to death; those who took a little were frost-bitten; and those who took no alcohol suffered no serious results from the exposure.

Alcohol dilates the peripheral vessels, and more blood gets to the body surface. Now, in cold weather we need all our heat inside to keep the vital organs warm. If we take alcohol the blood carries the heat to the skin, and it passes into the cold air. It makes us feel warm, because we feel the hot blood in the skin; but it uses up our heat, and we suffer for it. The travelers who took no alcohol felt chilly, but they kept their hearts warm at the expense of their skin and were all right. Those who drank warmed the surface of the body at the expense of the heart and lungs.

DEMONSTRATIONS AND EXPERIMENTS

1. Run the point of a needle which has been passed through a flame (to sterilize it) beneath the outer layer of skin upon the hand. Note that this "skin" can be separated from the layer beneath. No bleeding results from puncture of this layer. Why?

2. Wash the hands in warm water. Dry them and rub them together with force. The fine powder of scales which appears upon the surface is part of the outer horny layer of skin.

3. Obtain a sheep's kidney.

Strip the capsule.

Find the vessels which go to and from the kidney.

Note the difference in the appearance of the peripheral layer (cortex) and the inner substance.

Can you distinguish the pyramids?

The glomeruli and tubules can be made out in sections prepared for microscopic examination.

QUESTIONS

I. When coal is burned in a furnace, what are the products? What happens if the ashes are not taken away? What are the products and ashes which are formed by the combustion in the body cells? What would happen if these were not taken away? What are the organs called whose function is to rid the body of these waste products? How does the waste get from the cells to the blood? From the cells to the excretory organs?

II. What waste products are excreted by the lungs? How does the composition of the blood that comes away from an active muscle differ from that which enters it? What waste products are excreted by the kidneys? Describe the kidneys. What is a glomerulus? A tubule? What is the difference between the blood which flows into a glomerulus and that which flows out of it? Where does the water which it loses go? Describe the composition of the waste substances which are taken from the blood or built up from the blood by the kidneys.

III. What is urea? What are the ureters? What waste substances are excreted by the skin? Describe the skin. What other functions has it besides excretion? Describe the hair. What is its use? What are the sebaceous glands? What are the principal excretory structures of the skin?

IV. Describe a sweat gland. Of what does perspiration consist? What else besides perspiration is eliminated by the skin? What is insensible perspiration? What is the effect of the moisture in the air upon the elimination of heat on a hot day? On a cold day? What are the nails? Of what use are they? What becomes of the undigested part of the food?

V. Why must we keep up an active circulation? What practices serve to accelerate excretion by the skin? What is the proper clothing in winter? In summer? What is the effect of a daily bath? Why should we be regular in the operation of the bowels?

VI. How is the body heat produced? How is the temperature of the body regulated? Why does not the blood get much hotter upon a warm day than upon a cold one? What foods are great heat producers? What is the effect of the drinking of alcoholic liquors upon the maintenance of body heat? Does warm clothing economize food? Why do we need more covering while asleep than during the day?

CHAPTER XI

THE NERVOUS SYSTEM

THE special activity of all the organs of the body (the voluntary and involuntary actions which together make up the total activity of the organism) is controlled and regulated by a system of organs known as the *nervous system.* Through this control each motion of the muscles is regulated, and the secretion of a gland and the constriction of a blood vessel accomplished. Through the medium of this system all the organs work together for the common good.

When we desire an object that we see, as an apple, the idea of obtaining it is aroused in the mind. This thought of getting the apple sets in motion the machinery for obtaining it. Messages from the brain go to the leg muscles, and we walk toward it. Then messages go to the hands, and we reach out and take it; a message from the eyes goes to the brain, telling us where to grasp. We put it to the mouth. Then from the brain messages go to the jaws and tongue, and we eat and swallow the apple. So far all these acts, with the exception of a part of the act of swallowing, have been voluntary. The nervous system has been directing our motions, but we have had to think about the process, and could have stopped it at any time. After the apple is swallowed, a message from the stomach goes to the nerve centers, and the machinery for secretion of juice to digest

it is set in action. Then the digested apple is absorbed and carried to the cells by the circulation, the machinery of which is always going.

The action of secretion is an involuntary action. It is regulated by the nervous system, just as is walking, but it is done without our consciousness. So with the circulation of the blood.

Thus the whole process of taking in food and using it is under direction of the nervous system. If the connection between this system and the muscles is cut off, these muscles cannot act. We may desire the apple, but we cannot get it. If the connection with the stomach is cut off, the stomach will be there and the food will be there just the same as before, but no secretion will occur, and the food will not be digested.

The nervous system not only regulates each separate act, but by its connections and mental processes enables all the various functions, sight, movement, secretion, to work together for a common end.

I. THE ORGANS OF THE NERVOUS SYSTEM

The nervous system is made up of the *brain*, the *spinal cord*, and the *nerves*.

Speaking in a general way, the nerves carry impulses to the organs from the brain and cord, and from the organs back again. The brain and cord receive impulses by the nerves and send out impulses by them. They are the central office where all the reports are received, records kept, and directions issued. Thus, if the sole of the foot itches, this message goes to the central system. It is recorded here that scratching stops this itching, so the machinery for scratching the sole is set going and the itching relieved.

The *brain* lies in the bony skull. Continuous with the brain, the *spinal cord* extends downward from the *foramen magnum* of the skull, in the spinal canal of the vertebral column, to the base of the spine.

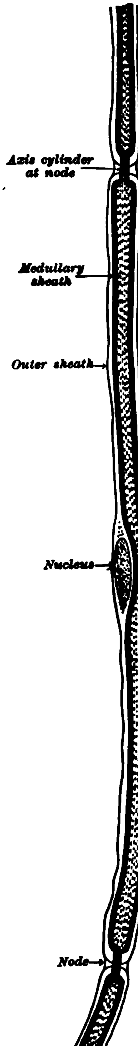
Brain and cord, showing nerves cut close to cord.

To and from the brain and cord run the nerves. They are distributed throughout the organs and structures of the body, connecting these with the central nervous system, the brain and cord.

The central system consists of nerve cells, and nerve fibers connecting these cells with one another and with the nerves. The nerves consist of nerve fibers continuous with the fibers of the brain and cord.

The nerves. The nerves of the body are of two kinds. One set carries sensations from the skin and organs to the central system. These are called *afferent* (Latin *ad*, "toward," and *fero*, "I bear") *nerves*. Others carry impulses from the centers to the parts. These are *efferent* (Latin *ex*, "from," and *fero*, "I bear") *nerves*. The afferent nerves arise in the organs of sense, as the eye, the taste papillæ of the tongue, the skin, and carry sensations from these inward. They are sensory nerves. The efferent nerves arise in the nerve cells of the brain and cord, and carry impulses outward.

The *structure* of both sets of nerves is the same. Most nerves consist of bundles of fine fibers held together by connective tissue. Each fiber consists of a central column or strand of soft protoplasmic substance, called the *axis cylinder*. This is inclosed in a sheath known as the *medullary* (*medulla*, the substance of the central canal of bone) *sheath*. Outside of this is another sheath, the *neurilemma* (Greek *neuron*, "nerve," and *lemma*, "husk"). The central axis cylinder and the outer neurilemma sheath are continuous throughout the nerve. The medullary sheath is broken at regular intervals. These breaks are called *nodes*. In the parts of the nerve between the nodes a nucleus may be found just beneath the sheath. The fibers have a white appearance and are called *medullated nerve fibers*.



A nerve fiber.

In some nerves there is but one sheath, the neurilemma. These are called *nonmedullated fibers*.

Nerve ganglia. In the course of some nerves occurs a slight enlargement called a *ganglion*. A ganglion is made up of cells mixed with fibers. These *ganglion* (Greek *gagglion*, "a knot") *cells* are nerve cells. They are large cells with a nucleus and an irregular outline. Each cell has many branching processes. One process of each cell is continuous with the axis cylinder of a nerve.

The cord. The *spinal cord* is a column of white appearance, lying in the spinal canal of the vertebral column. It is continuous at

the top with the brain. At the base it tapers to a fine filament. Its length is about eighteen inches, its width half an inch. Its shape is cylindrical.

Along the front runs a deep furrow, the anterior fissure. At the back is a similar furrow, the posterior fissure. Between these fissures is an isthmus of cord substance connecting the right and left halves of the cord. In these fissures runs connective tissue carrying blood vessels.

Section of spinal cord, with nerves.
a, ganglion in root; *s*, sensory root; *m*, motor root.

In cross section the cord is seen to consist of a superficial layer of white substance and a central zone of gray substance arranged in the form of an H, each bar of the H being a crescent with two horns.

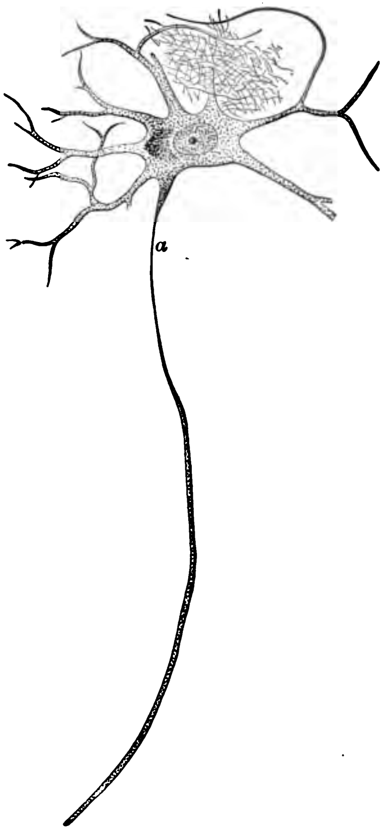
The white matter consists of nerve fibers, most of which run lengthwise in the cord.

The gray matter consists of cells, among which many white nerve fibers and gray nonmedullated fibers run in all directions. The cells are nerve cells, resembling those described as ganglion cells.

The spinal nerves. From the spinal cord thirty-one pairs of spinal nerves are given off at intervals along the cord. These nerves emerge through the *intervertebral foramina* between the vertebral arches. Each nerve has two roots—an *anterior root* which enters the anterior region of the cord, and a *posterior* which enters the posterior part of the cord. Upon the posterior root is an enlargement known as a ganglion. The two roots unite in the bony foramen to form the nerve, which proceeds to the muscles or skin or some organ.

In the anterior root the white fibers of the nerve run to

the anterior horn of the gray matter of the cord. Here a fiber unites with a cell of the gray matter. As described in connection with ganglion cells, one fiber from a nerve cell becomes the axis cylinder of a nerve fiber. The anterior root carries the *sensory* nerve fibers of the spinal nerve.

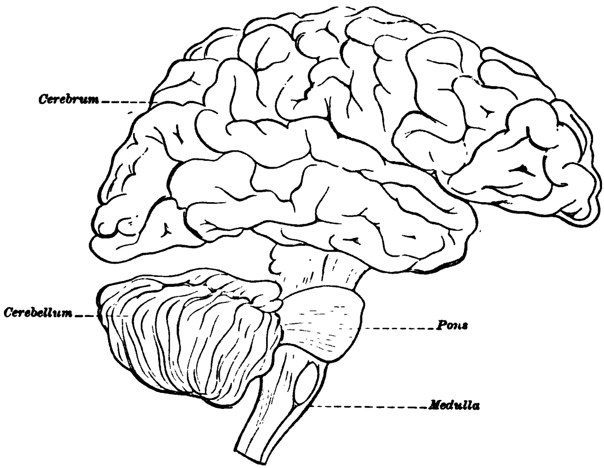


Nerve cell.
a, axis cylinder.

In the posterior root the fibers take their origin from the cells of the ganglion on the root. These ganglion cells are connected again with the cells of the posterior horn of the cord, but by fibers of the nonmedullated kind. The posterior roots carry the *motor* nerve fibers, which take messages from the cord to the parts. If this root is cut there will be feeling in the part supplied by this nerve, but no power to move. Each spinal nerve, then, consists of a nerve trunk carrying both sensory and motor, afferent and efferent nerve fibers, which decussate, or cross, at the cord, the sensory fibers entering the cord by the anterior root, the motor by the posterior root.

The cord is thus made up of nerve cells connecting with the fibers of the nerves, and also of fibers connecting these same cells with the cells of the brain above.

The brain. The brain lies in the skull. It consists of several parts. The lower part, attached to the cord, is called the *medulla oblongata.* Attached to the medulla and lying

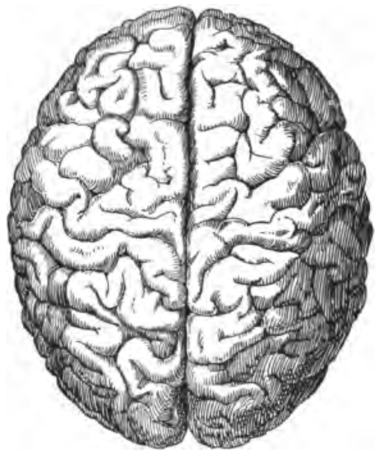


The brain.

mostly behind it is the *cerebellum* (Latin, "little brain"). The two lateral parts of the cerebellum are connected by a fibrous bundle running in front of the medulla, the *pons.* Above the pons the bundles of nerve fibers of the medulla are collected into two pillars, the *crura* (Latin *crus,* "leg"—legs of brain) *cerebri.* These pillars diverge and run upward to the *cerebrum* (Latin, "brain"), one to each hemisphere.

The *cerebrum* makes up the larger part of the brain. It consists of two hemispheres connected by a band of fibers,

the *corpus* (Latin, "body") *callosum.* The surface of the hemispheres is furrowed by *convolutions* (Latin *con,* "together," and *volvere,* "to roll") separated by *fissures* (Latin *findere,* "to split"). Between the two hemispheres is a deep median fissure. The surface of the brain is gray, being composed of gray matter. The deeper parts of the brain are white, consisting of fibers running from the cells of the gray substance into the crura and cord below.



Upper surface of cerebrum, showing convolutions and fissures.

The outer gray part, or *cortex* (Latin, "bark"), of the cerebrum consists of many nerve cells connected by many nonmedullated nerve fibers.

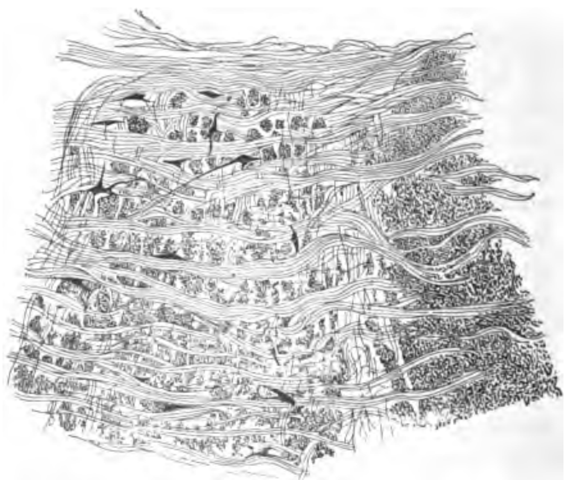
The deeper white part consists mostly of white medullated nerve fibers, each with an axis cylinder starting from a nerve cell in the cortex.

The lower parts of the brain, the crura and medulla, consist, like the cord, of mixtures of these gray and white substances. The white fibers run from the cerebrum through the crura and medulla, to become fibers of cranial nerves or to join cells of the cord, which are the origin of spinal nerves. Both the fibers which leave the brain, the motor, and those which come to it, the sensory, cross to the other side of the body from that on which they started before reaching the organ or nerve cells to which they go. This is called the *decussation* (Latin *decussare,* "to divide crosswise") of the nerves. Consequently an injury to the right

side of the brain causes a paralysis of the left side of the body.

The cranial nerves. Twelve pairs of nerves arise from the brain, each nerve supplying a corresponding part of the body on the right or left.

The *first* pair are called the *olfactory* (Latin *olfacere*, "to smell") *nerves*. They arise from the olfactory bulbs on the under side of the cerebral hemispheres and run to the nose. They are the nerves of the sense of smell.



Section of brain; cells and fibers.

The *second* pair are the nerves of *sight*. They arise from the region of the crura and run to the eyeballs.

The *third* and *fourth* pairs supply the eye muscles. They are motor.

The *fifth* pair arise by a motor and sensory root like the spinal nerves. Each nerve divides to three principal

branches. It supplies motion to the face and jaw, and is a sensory nerve of part of the face, eyelid, and tongue.

The *sixth* pair supply one muscle for each eye.

The last six pairs arise from the medulla.

The *seventh* supply the muscles of the face and scalp.

The *eighth* are the nerves of hearing, running to the ears.

The *ninth* supply the pharynx with motion, and are the sensory nerves of taste.

The *tenth* supply the larynx, the muscles of respiration, and the heart, stomach, intestines, and liver. They are called the *pneumogastric* (Greek *pneumon*, "lung," and *gaster*, "stomach") *nerves*, from their important connection with the lungs and stomach; also the *vagus*, or wandering nerves, because they go to so many organs.

The *eleventh* supply the muscles of the neck.

The *twelfth* supply the muscles of the tongue.

The meninges. The brain and cord are surrounded by protecting membranes. Closely adherent to the brain and carrying the blood vessels is a delicate membrane, the *pia mater* (Latin, "tender mother"). Outside, close to the skull wall, is a firm membrane, the *dura mater* (Latin, "hard mother"). A thin layer of cells lining the pia, and another layer lining the dura, together make the third membrane, the *arachnoid* (Greek *arachne*, "a spider's web," and *eidos*, "resemblance"). In the space between the two layers of the arachnoid is a liquid, the *cerebro-spinal fluid.*

Inside the brain and cord is a continuous canal which contains fluid. In the brain this canal expands to several large spaces called *ventricles.*

The sympathetic (Greek *sun*, "together," and *pathos*, "feeling") **nervous system.** In addition to this main nervous system of brain, cord, and nerves, there is a second nervous system appended to it, the sympathetic system. This is made up of a series of nerve ganglia which lie along the

outside of the vertebral column from skull to coccyx. Each ganglion is connected to the ganglia above and below, thus forming a chain. Branches from many spinal nerves and some of the cranial nerves connect this system with the central system. From this chain nerves pass to the viscera of the abdomen and thorax. It is principally the nerves from this system which control the muscular action in the blood vessels.

The fibers of many of these nerves of the sympathetic system are nonmedullated.

II. THE FUNCTIONS OF THE BRAIN AND THE SPINAL CORD

Psychical (Greek *psuche*, "mind") **centers.** The *cerebral hemispheres* are the seat of sensation, volition, and intelligence.

Any contact with the outer world, as a touch, a taste, a sound, a pin prick, or a blow, is perceived here. If the brain is benumbed, touch or even pain is not felt. A man whose brain is benumbed by the administration of ether does not know that the dentist is pulling his tooth, or feel any pain when it is pulled.

All voluntary acts originate here. The cells from which voluntary movements of the hand originate are situated in a certain part of the hemispheres. If this region of the brain is injured the hand cannot be moved, however hard the man may try to move it.

All consideration of the meaning of things is here. A man whose brain is stupefied by alcohol does not know the difference between a hat and an umbrella. He does not understand what is said to him.

Reflex (Latin *re*, "back," and *flectere*, "to bend") **centers.** The spinal bulb or medulla and the cord are the seat of many of the processes of life which we call *automatic* and *reflex*

acts (Experiments 1 and 2. p. 233). The act of breathing is an instance of an automatic action. This process goes on without our consciousness or will. We can stop it for a short time, or change its rate by the act of the higher brain, but as a rule it is regulated from the medulla. It goes on in frogs after the cerebrum has been removed. There are many instances of reflex action, as the drawing up of the foot when the sole is tickled, the working of the eyelid at a bright light. The person does not stop to think before acting in these cases. The parts act for themselves. These reflex acts can be controlled by the will, as we need not draw up the foot if we previously determine not to. There are fibers which run from the cerebrum to these centers. If we send a current from the brain through these, we stop the act; but as a rule the act goes on without interference. There are some actions with which the conscious will cannot normally interfere, as, for instance, the beating of the heart or the secretion of the intestine. They are purely automatic, but they are regulated by the nervous system. The secretion of the intestine is a reflex act. This is not going on continuously. When food reaches the intestine a message goes to the reflex center, the machinery of secretion is set in motion by a counter message from the nerve center, the secretion of the pancreas begins to flow, the bile which has been stored in the gall bladder begins to pour into the intestine, and digestion is accomplished. Most of the processes essential for existence are of this nature. They do not require the attention of the psychical centers, the mind.

Metabolism in the brain. Whenever we think or act, perceive an odor or hear a sound, some change takes place in a cell of the nerve tissue in the brain or cord. There is a combustion of tissue here, just as in the muscle cells when those organs contract. The brain cells are wasting and building all the time, just as are the cells elsewhere.

Localization. The different functions of the body have their own center in a special area of the brain. Thus, the function of speech is in one place, that of writing in another; the movements of the hand have their centers in one part, those of the foot in another. Sometimes we have an injury or disease of the brain which affects a small part, perhaps one of these special centers only, and then the man can perform every function as before, except the function whose centc is affected. Thus, he may be able to think, walk, talk, but not move his right hand. He may know what he wishes to say, but not be able to say it, if his speech center is affected.

Hygiene of the nervous system. The nervous system, like the muscular system and the skeleton, is developed by use. Just as the muscles are made stronger by running and rowing, the brain is made stronger and more efficient by study and thought and action; and, like the other organs of the body, the brain, if it is not exercised and cared for, will be less developed and less useful than it should be.

The soundness and training of the nervous system are of first importance, since all the functions and actions of the body and its organs are regulated by it. A body with a weak or untrained brain is like an army with an incompetent general. However strong a man's muscles may be, unless he has a sound nervous system to control them, he cannot do good work or endure sustained exercise with them. Unless he has a brain which has been trained by thought and experience, he cannot properly direct his work, and much of his strength will be wasted. Thus, a trained carpenter can build a house twice as quickly and twice as well as a much stronger man who has not learned the trade.

A man may sustain the health or soundness of his nervous organs by taking plenty of food to nourish them, plenty of sleep to rest them, by exercising them in thought and action,

and by avoiding all practices which injure them, as overwork or indulgence in alcohol and other substances which poison them.

Education. The training or exercise of the nervous system is the business of *education* (Latin *ex*, "out," and *ducere*, "to lead"—to lead forth).

Nature's method of training or education consists in the formation of *habits* (Latin *habere*, "to have"). Thus, the child learns to walk, to talk, and to swim by imitation of others. At the start the processes take some thought and many trials for their accomplishment, but when learned they are accomplished automatically, without any conscious thought as to the process. They become habits. In the same way the child acquires the habits of obedience and of conscience. He grows up to obey his parents without reasoning why in each instance. He feels that he must not do anything which he knows to be wrong, must not tell a lie to avoid punishment. This is his conscience habit, which keeps him upright without his reasoning about it.

In the further education of the child or man, we adopt and utilize this same method of nature, the formation of habits.

Object of training. Thus, in learning to write, the child studies the formation of each letter in repeatedly copying the letters and putting them together. Finally he writes them offhand without thinking about their formation and without a copy. The wood carver or the weaver becomes so expert that the fingers work almost without thought.

At first we think much about the right way to do a thing. We study each step carefully, and then we do it frequently. Finally we do not think of the steps at all; we wish to do it, and the thing is done almost without thought.

As the result of such education the child or man becomes so accustomed to these right habits of doing and thinking that he becomes confirmed in good habits and well doing.

Object of study. The mind is trained by the study of mathematics, language, physics, philosophy, to develop its powers of reasoning and thinking. It is not so much the facts which the child learns as the habits of quick and accurate thinking which count. With these habits he is in a position to make the most of the knowledge and experience which he acquires later. If he has gained the habits of accurate observation and of perseverance and industry, he is well equipped for his progress through the world.

Education is by no means confined to the schools. The greater part of it is obtained in the home and in the community about us. At home the boy is given good books, that he may read of the good deeds and noble lives of the world's history. He is taught courtesy and charity, that he may make those about him happier. He is taken to walk in the woods and fields, and instructed in the story of the rocks and plants and animals, that he may come to love nature and to find an interest in studying its works. He is taken to see great works of art and to hear good music, and taught to care for poetry, that he may acquire refined tastes and see more of the grace and beauty in life.

In this education it is not enough that children shall read books or see paintings or sculptures. They must be taught to appreciate the meaning which is in the work, to feel the spirit which inspired the writer or painter who conceived it, and to understand the thoughts and ambitions and passions which have molded the lives of the men and women who have made the history of which they read. If they learn these things, to them life becomes filled with an interest and a joy which can never die.

> "He ate and drank the precious words,
> His spirit grew robust,
> He knew no more that he was poor
> Or that his frame was dust;

He danced along the dingy days—
And that bequest of wings
Was but a book. What liberty
A loosened spirit brings!"

A most important habit to acquire is that of self-control. It is this quality perhaps beyond all others which distinguishes manhood. The emotions of sympathy, love, pity, enthusiasm, religion, are all excellent elements of our characters. They help to ennoble us and to lead us to strong endeavor, high thought, and worthy action. But they lose much of their usefulness if they are not controlled by judgment and a sense of justice and right, so that they are allowed to sway us only for the greater good of those about us. More especially should the passions of anger, jealousy, sensuality, and the many ignoble impulses which arise from the desire of possession be controlled.[1] In the submission to these lies a great part of the woe and crime which darken the pages of history.

True happiness comes not through the gratification of the desires for the material things of the world about us, but from the possession of a well-balanced mind which can discern the real treasures of life, and a spirit inspired with the pursuit of truth.

Everybody has affinities for truth and culture. If they are developed the man will take his pleasure in good pursuits; if not, he will indulge in sensual pleasures. Everybody should be athletic, but he should also be clever and

[1] There is physiological necessity for correct emotional conditions of the mind. Professor Gates of the United States Commission of Biological Research has shown by chemical tests that the human tissues and fluids are affected by emotions. "He has found that the blood of a large number of people after an attack of ill temper responds uniformly to a certain chemical test; the blood of a large number after attacks of jealousy responds to another chemical test; of others, after grief, to another; and so on through the line of emotional conditions. And never has it failed that the chemical generated by any malevolent, inharmonious mental condition is of an acid, acrid, poisonous nature." — Maria L. Pratt, M.D., of Durant Gymnasium, in Report of National Educational Association, 1896, p. 931.

refined. In these days a clever head and a well-trained mind will accomplish far more than muscular strength.

One-sided development. Care must be observed in this training not to become developed entirely in one direction. We see too many men whose brains are admirably developed for business, but who have no interest in art or literature. Too many, on the other hand, are so engrossed in the pursuit of one kind of knowledge that they are ignorant of the truth which underlies development in the more practical and essential aptitudes of human nature.

Sleep. In exercise of the nervous system we must be careful not to overwork. We must be sure to get enough sleep. The muscles rest between periods of exercise, the stomach rests between meals, but the nervous system is always active during waking hours. Whenever we think or move or see or feel the nervous system is in action. Therefore it gets complete rest only in sleep. Even here parts of it are active, but the most of it rests. Every one should allow eight hours for sleep, and the sleep should be taken at a regular time, as nature likes regularity. We sleep best at night, as the darkness is favorable to the condition.

It is reasonable to suppose that the cells of the brain and nerve tissue become depleted after labor and need a period of rest in which to rebuild their substance. Careful histological investigations show that this supposition is a true one. Changes in the character and contents of the cells can be observed during the working or resting stages.[1]

The danger of overworking the brain or the body is espe-

[1] Professor C. F. Hodge of Clark University, with other physiologists, has conducted numerous experiments relating to the subject, which are full of interest. One of the results reached has been the observation that after a severe effort a rest of twelve hours is required to enable the cell to return to its normal condition; that often even twenty-four hours is scarcely sufficient for this purpose. It thus appears that there is physiological basis for a periodical rest day in which the worn-out cells may be able to recover their store of energy. — Dietetic and Hygienic Gazette, August, 1898, p. 518.

cially great in these days of the telephone, the telegraph, and express trains. A business man to-day can transact many times as much business in twenty-four hours as his grandfather could in a week. To do this, however, he has to use his mental faculties to the utmost. Every one, especially brain workers, should make a point of taking a good vacation twice yearly.

One of the best means of rest is a change of occupation. To rest the brain it is not necessary to vegetate. It is simply necessary to take the interest off one set of ideas and place it upon another. A man gets more rest in reading a good book or in seeing a good entertainment after a hard day's work than if he sat about doing nothing. Travel, or sojourn in the country where he can ride and climb, play golf or ball or cricket, will do a business man far more good than sitting about the piazzas of summer hotels at fashionable watering places.

In connection with this subject the custom observed in Christian countries of suspending all business every seventh day is a most beneficial one, one which doubtless adds materially to the health and longevity of the people.

Alcohol. The nervous system is very susceptible to the influence of alcohol. Much of the harm which this substance does is accomplished through its influence here.

The first effect of the drinking of alcoholic liquors upon the nervous system is to cause a sense of exhilaration. The man feels lively and like making effort. Now, this very first effect of alcohol is a bad one, for the sense of exhilaration and power is a false sign. The man thinks that he can do more work, but in reality he can do less. His sense of fatigue is paralyzed, so that he does not know when the muscle centers have exhausted themselves.[1] Thus he goes

[1] The view of Schmiedeberg that the action of alcohol upon the nerve centers is always a paralyzing one is now accepted by most physiologists.

on working at the expense of his health. In this way one of nature's safeguards against overwork is broken down by the creation of this false sense of exhilaration. The heart and other organs work more rapidly for a time and wear themselves out the sooner.

In the second place, this sense of exhilaration which people get from alcohol is followed by a sense of relaxation and inertia. When the effect of the alcohol is gone, the man feels less able to work than before. To get rid of this feeling of laziness and distraction he frequently takes more liquor. After a time small amounts of liquor cease to relieve the relaxation.

Alcohol habit. The man begins to take larger amounts, and thus what is known as the *alcohol habit* is formed. The man has so relaxed his system by the use of alcohol, and has become so dependent upon it for the feeling of energy which he desires, that he thinks he cannot get along without it.

Now he finds that the constant or large doses which he takes are injuring his health and capacity to work. His heart is less able to stand exertion, his mind is less clear. He determines to stop the use of liquor, or reduce it. But now he finds that he cannot. The alcohol appetite has so grown upon him that he cannot resist it. His will has been weakened by the indulgence, and cannot defend him against his enemy. Thus he may go on until his health is gone and his business affairs are ruined through incapacity and neglect.

Such a career as the above is no uncommon one. Many men who begin by drinking beer or wine or cider in what is called moderation acquire the alcohol habit. It is this power of alcohol upon the nervous system to establish a "habit" which is one of its most dangerous qualities, and which makes it a thing to be avoided. No man knows, when he takes his first glass, whether it may not be his fate to become a victim of this habit.

DEMONSTRATIONS

1. Cross one knee over the other, and let the leg hang loosely. Strike the upper leg sharply with the hand just below the kneecap. The lower leg will jerk suddenly forward. This is an example of a muscular movement occurring without the intervention of any thought upon the part of the individual.

2. Tickle the nose with a feather. The sneeze which follows is a reflex act of the body to rid itself of the source of irritation to the mucous membrane of the nose.

3. Pass the hand rapidly close to the eyes of the pupil next you. The rapid winking of the lids is an example of an involuntary action established to protect the eye.

4. Note the deep and rapid respiration which replaces the ordinary respiration after exertion, as running. This is an automatic action in response to the need of more respiratory exchange to supply the increased combustion resulting from the increased muscular action.

QUESTIONS

I. How are all the vital processes of the body, the digestion, circulation, and so forth, regulated so that they all go on together in time and place for the common good? In what part of the body must there first be an action that a muscle may contract, or that an arm or leg may be moved? What are the organs of the nervous system? What is the function of each part of this system? Of the nerves? The cord? The brain? How are nerves classified according to their functions? Describe a nerve. What is a nerve ganglion?

II. Describe the spinal cord. How many nerves join the cord? What two sets of fibers does each spinal nerve carry? Where is the brain situated? Describe the brain. In which side of the brain are located the cells which regulate the action of the right side of the body?

III. Name some of the cranial nerves. What are the meninges? Is the nerve of sight motor or sensory? Is the nerve of hearing motor or sensory? Is the pneumogastric nerve motor or sensory? Classify the spinal nerves as motor or sensory.

IV. What is the sympathetic nervous system? What is the function of the cerebral hemispheres? What kind of acts originate here? Can

the muscles act if the nerve which connects them with the brain or cord is cut? What kind of acts take place without the use or intervention of the brain? Describe a reflex act. Name some of our actions which are done without our thinking. What occurs in the brain cells whenever we think or perform a voluntary action?

V. Can the brain and nerve system be developed? How? What is the training of the nervous system called? What are habits? What is the chief end of the study of mathematics and grammar? Why should we read good books? When does the nervous system rest? Why is the nervous system susceptible to the action of alcohol? What is the most dangerous feature in regard to the action of alcohol upon the nervous system? Can a man tell when he is forming the alcohol habit?

CHAPTER XII

TOBACCO—OPIUM—COCAINE

BESIDES alcohol there are other substances used by men against the use of which, on account of their harmfulness to health and development, every one should be warned. Such substances are tobacco, opium, cocaine,

Tobacco. Among these substances the one most commonly used in this part of the world is tobacco. It contains a very poisonous substance known as nicotine. The smoke of tobacco contains several irritant substances formed from the combustion of the tobacco fiber and the nicotine. When this smoke comes in contact with the mucous membranes of the mouth and upper air passages it has an irritant action upon them. In constant smokers this irritation results in a relaxation of the structures of the membrane, with changes in the cells and the secretions. These changes frequently end in a condition of chronic pharyngitis. If you look at the throat of habitual smokers you will often see pearly patches on the membrane, showing areas of chronic inflammation. The throat will have a red, beefy appearance, instead of the moist, pink appearance of the normal throat. This chronic condition of the membrane makes the throat susceptible to exposure to cold and disease infection, so that the smoker is less able to resist the diseases of the mouth and throat than the abstainer.

This condition of irritation of the mucous membranes is very detrimental, but it is not the most serious effect of tobacco smoking. The pyridine and other substances which are taken in with the smoke, and the nicotine which is sucked in from the tobacco, are absorbed into the system, where they act as poisons. These substances appear to poison the red corpuscles of the blood, destroying their hemoglobin and diminishing their oxygen-carrying capacity. Lack of oxygen in the tissues follows, and thus development of the organs and the body is hindered. You will often notice the pallor and stunted development of youths who are habitual smokers. The skin has a sallow, unhealthy look. This is particularly true of those who smoke in boyhood, before their development has been completed. The growing tissues are especially susceptible to the influence of poisons. Any boy who smokes before the age of twenty-one runs the risk of growing up with stunted development, with weak muscles, a poor brain and nervous system, a weak heart, and no power of endurance.

The poison of tobacco has a marked effect upon the heart. The action of the heart is much weakened; its beat becomes irregular and rapid with any exertion. Many a boy or man who has smoked without any thought of harm from it finds, when he comes to be examined for admission to some athletic contest or to the army, that he is debarred owing to the fact that he has a "tobacco heart."

Smoking has a bad effect upon the nervous system. The effect may appear to be soothing or even stimulating for the time, but it ends by making the person irritable. Through its poisonous effect upon the nervous system, the functions which are regulated through this system are disturbed. The hand becomes unsteady, the eye less sure. An archer or rifleman has often had his skill fail through the effect of tobacco. Athletes in training are forbidden its use.

The sickness, faintness, dizziness, and vomiting which often accompany the first trials at the use of tobacco ought to be a warning of its poisonous nature. But if this fails to deter a boy or man from the practice, the knowledge that it stunts the growth, lessens the strength, injures the mind and the power of endurance, should do so.

Statistics made among large numbers of men in the great seats of learning of the world tend to show that a large proportion of the rankholders are tobacco abstainers. If men who have got their development find that tobacco is injuring their health, they can stop the use, provided their craving for it has not become stronger than their wills, and may regain their health. But the boy who has hindered the growth of his bones and brain and muscles by the use of tobacco can never gain the development which he has lost. There is a time for development, which he has wasted, and for every year of that time which he has misused he must pay during his whole life. He has left only so much room for strength, and work as he may in later years he can never reach the strength which he might have had if he had not hindered the growth of his organs in youth.

Opium is a gummy substance which contains several poisonous constituents, as morphine and codeine. Laudanum and paregoric are familiar preparations of this substance.

Many people take it first for the relief of pain, and get in the habit of using it, so that when they try to stop they find that they cannot. They have formed what is known as the *opium habit*. For, like alcohol, this substance forms a "habit" in the consumer, so that after he has taken it for some time he is unhappy and even ill without it. If he continues to take it, it will destroy his health, his capacity for work, and finally his mind. He lies, steals, and commits other crimes without compunction.

The effect of a single dose of opium or morphine is to

cause a diminished sensibility, to allay pain, and to produce an unnatural sleep. A person who has taken it once is tempted to try it again and to take it for all sorts of pain, and thus he finally forms the opium habit.

The use of opium as a habit is less common with us than in some Eastern countries, but it is too common.

Some other substances which are used for the relief of pain are chloral and cocaine.

The use of *chloral* may lead to the *chloral habit*. It is used by people to procure sleep as well as to relieve pain.

Cocaine is likewise used to relieve pain, and leads to the *cocaine habit*, which is very difficult to cure.

In addition to the above drugs there are several other so-called medicines against the indiscriminate use of which people should be warned. Among these are phenacetine, antipyrine, and many other headache medicines. These medicines may relieve the trouble for the time, but they are dangerous. In getting rid of the headache you may get some new disturbance from the poisonous action of the drug.

Many of the patent medicines for the relief of cough or pain contain opium. There is but one safe rule, which is to take medicines only under a physician's advice. You will suffer less in the end from taking no medicine than from the use of medicines without professional advice.

QUESTIONS

Is tobacco ever useful from the point of view of the body needs? Is it ever harmful? What are its effects upon the membranes of the throat and air passages? What may the effect of smoking be upon the nutrition of the body if practiced during the period of growth? What are the dangers attending the use of opium? Of cocaine? What are the objections to taking drugs without a physician's advice?

CHAPTER XIII

THE SPECIAL SENSES

Sensation. When any impulse is brought by the afferent nerves to the brain from any part of the body and causes a feeling there, a consciousness that something is happening, we call it a *sensation* (Latin *sentire*, "to feel, perceive"). Thus, when a piece of ice touches the hand we have a sensation of cold. When sugar is placed upon the tongue we have a sensation of taste.

Some sensations are very definite. We can localize the part of the body from which they come, and can recognize the object which causes them. Such are the sensations of touch, of pain, of cold, of sight. When anything touches the hand, we have the sensation of touch; we know where the touch takes place, and we may be able to tell from the special nature of the sensation what the object is which is touching us.

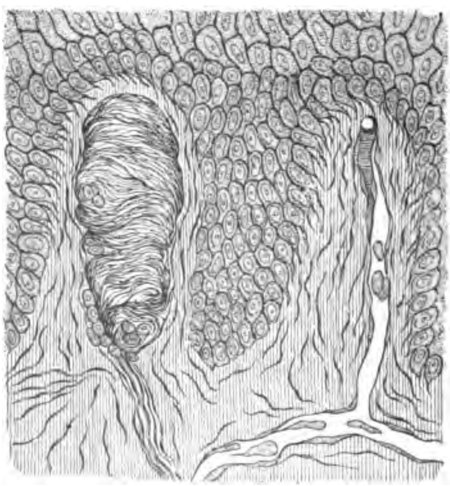
Other sensations are indefinite in their character and localization. Such are the sensations of hunger, of mental pleasure, of fatigue. We cannot say that these sensations come from a particular part or a particular outside object.

The special senses. A large proportion of our definite sensations come to us through what are known as the special senses. Almost all our knowledge of the outer world comes to us through these.

The special senses are usually described as five in number, sight, hearing, touch, taste, and smell. To these must be added the sense of temperature, the sense of pressure, and perhaps the muscular sense.

All of these special senses have special organs in which the sensory impulses originate.

Sense organs. Each special sense organ may be placed in a special part or may be distributed in several parts. Thus, sight is located in the eyeball, hearing in the ear. The special organ of touch may be located in the skin or in the mucous membranes. Taste has a special nerve organ located in the mucous membrane of the tongue.



Tactile corpuscle in the skin.

The special sense impulse originates in the special organ, and is carried by the nerve from that organ to the brain, where the sensation occurs.

Touch. The organs of the sense of touch are located in the skin and in some mucous membranes. In some papillæ of the dermis are placed small oval structures composed of cells from which a sensory nerve arises. These oval structures are called the *tactile* (Latin *tangere*, "to touch") *corpuscles.*

Some of the fine endings of these nerves of touch run even into the cells of the epidermis. The organ of touch,

however, is always the cells over a nerve ending, not the nerve itself. The touch of the nerve end itself causes pain, not the distinguishing sensation of touch. This sensation not only tells that an object touches us, but also the character of the object, whether hard or soft or rough.

This sense is most delicate at the tips of the fingers, the tip of the tongue, and on the face. It is least delicate upon the back, owing to the smaller number of tactile corpuscles there and the thicker epidermis. If we place the two points of a compass one tenth of an inch apart upon the tip of the finger or tongue, we can feel each point; upon the back, the points even two inches apart feel as one point.

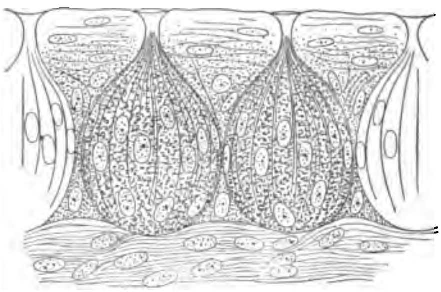
Tongue, showing papillæ of taste. *a*, circumvallate papillæ; *b*, papillæ.

The sense of *temperature* also is placed in the skin. This sensation arises from special organs distinct from those of touch.[1] The fact that these sensations of touch, pain, and temperature, which are received in the skin, are carried by separate nerve fibers, is demonstrated by certain diseases. Thus, there is a disease of the spinal cord in which the patient loses the sense of pain, but not that of touch, in a certain part; also one in which the sense of touch is lost, while that of pain is intact.

[1] This sense can be cultivated. The blind by training acquire a very delicate sense which enables them to distinguish by touch objects which to our sense are alike.

Taste. The organs of the sense of taste are located in the mucous membrane of the tongue and palate. This membrane is raised into numerous elevations, or papillæ. In these papillæ are the endings of the nerves of taste.

The papillæ are of three kinds. The *filiform* (Latin *filum*, "thread," and *forma*, "form") papillæ are long and slender, and placed over the front of the tongue. They contain the organs of the sense of touch in the tongue. The *fungiform* (Latin *fungus*, "mushroom") papillæ are mushroom-shaped, with broad crowns and slender stems. The *circumvallate* (Latin *circum*, "around," and *vallum*, "a trench") papillæ are large mound-shaped papillæ with a ditch or moat about them. They are situated in double rows, forming a V on the back of the tongue. These fungiform and circumvallate papillæ contain the *taste buds.* Each taste bud is made up of epithelial cells arranged like the petals of a rosebud, the inner cells having fine processes reaching to the surface of the papilla. The fine nerve ending of the glossopharyngeal nerve of taste runs into these inner cells. When sugar is placed upon the tongue the fine processes of the buds are stimulated, and this sensation is transmitted by the nerve to the brain.



Taste buds.

Tastes. These taste buds have to act for four kinds of taste—sweet, bitter, sour, salt. With most people the bitter tastes are perceived at the back of the tongue, the sweet at the tip. Substances to be tasted must be in solution. When the mouth is dry, as in fevers, the taste is very weak.

Many so-called tastes are flavors, and are really distinguished by the sense of smell. Such are the flavors of meat or vegetables. If we hold the nose when we eat an onion we cannot tell what we are eating.

Smell. The organs of the sense of smell are situated in the mucous membrane lining the upper part of the cavity of the nose. The outer openings of the nostrils, which we see, lead to the nasal chambers. Behind, these chambers open into the pharynx. Into these chambers from the sides protrude three spongy, scroll-like bones, the turbinates. Over the whole inner surface of the chambers lies a mucous membrane. In this membrane in the upper chambers many of the epithelial cells on the surface are rod-shaped. To these rod-shaped cells the nerve endings of the olfactory nerve go. Any odor which floats in the air and is drawn through the nose stimulates these rod cells, and produces the sensation of smell. The lower part of the nostril near the opening is lined with columnar cells having cilia.

The air is warmed in passing through the nose to the lungs. It takes up moisture from the walls. It is freed from dust and bacteria by the hairs at the entrance to the nostril.

The sense of smell is often useful in enabling us to discover the presence of noxious substances, as decaying matter, coal gas, etc.

The sense of sight. The organ of the sense of sight is the eyeball. The *eyeball* is a globular structure lying in the bony orbit of the skull. It is placed well forward in the face so that all objects in front or at the sides of the head will come in sight of it. At the back it is connected with the brain, so that it may be called a bay window of the brain, thrown out to command a clear and full view of the world about.

The eyeball is covered in front by the *eyelids*. These lids

are curtains which may be raised or lowered before the eye to protect it from light or dust. They are made up of fibrous connective tissue lined with skin on the outside, and on the inside by a membrane of thin epithelial cells, the *conjunctiva*. This membrane lines the inside of the lids and passes from these over the front of the eyeball. At the edge of the lids are the eyelashes, which serve to keep dust from the eye.

The lids contain striate muscle and can be opened and closed at will. When a strong light strikes the eye they close by a reflex, as described in the chapter on the nervous system.

Motions of the eyeball. The eyeball is moved by six muscles which attach to the walls of the orbit. One muscle, the *external rectus*, turns the ball outward, as when we look off to the right with the right eye. The *internal rectus* turns the ball in toward the nose. The *superior rectus* turns the ball upward, the *inferior rectus* downward. Two other muscles, the *superior* and *inferior oblique* muscles, aid in turning the eye.

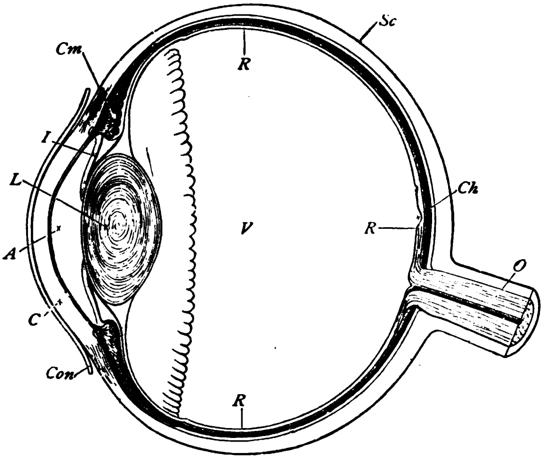
When we look at a near object close to the nose, the internal rectus of each eye contracts and points both eyeballs inward.

Each orbital cavity is padded with fat, which makes a soft cushion for the eyeball. At the outer side of each orbit is a small gland, the *lachrymal* (Latin *lachryma*, "a tear") *gland*, which secretes the tears. This gland is continually secreting a small amount of fluid which washes the front of the eyeball and drains away by small lachrymal ducts to a cistern sac, which empties it through the *nasal duct* to the cavity of the nose.

The structure of the eye. The eyeball is a sphere with a prominent bulging portion in front; that is, it consists of the segments of two spheres. The front bulging part,

through which we see the mottled-colored ring and the dark circle in the center, is the *cornea*. This is attached all about to the white coat of the eye, the *sclera* (Greek *skleros*, "hard"). The cornea and sclera are made up of fibrous material, and together form the outer coat of the eye.

Just inside the cornea, and seen through it, is a colored ring, the *iris*, inclosing a dark circular opening, the *pupil*. Between the cornea and iris is a clear watery substance, the *aqueous* (Latin *aqua*, "water") *humor*.



Plan of eyeball.

O, optic nerve; *R*, retina; *V*, vitreous humor; *L*, lens; *C*, cornea; *Con*, conjunctiva; *Sc*, sclera; *I*, iris; *A*, aqueous humor; *Cm*, ciliary muscle; *Ch*, choroid.

The iris is differently colored in different people. Thus we have blue eyes or gray eyes. The iris contains muscle, and can contract and dilate, changing the size of the pupil. The iris is continuous with a second coat of the eye, which runs inside the sclera, the *choroid*. This choroid coat, at its junction with the iris, is thrown into folds, like the

tucks of a dress. These folds are called the *ciliary* (Latin *cilium*, "hair") *processes.* The choroid coat carries blood vessels to feed the eye. Its inner layer is black, being lined with pigment granules.

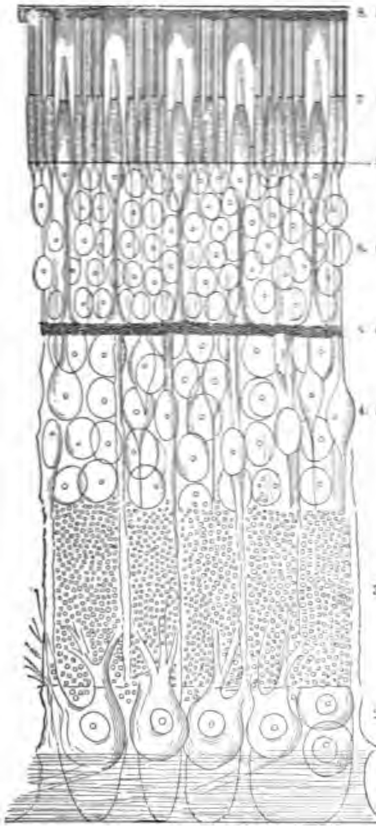
The *pupil* is a circular opening bounded by the iris. At the back of this opening is the *crystalline* (Greek *krustallos*, "clear ice") *lens.* This is a double convex, transparent structure, like the lenses of magnifying glasses. It is held by a sheet ligament from the choroid, the *suspensory* (Latin *sub*, "under," and *pendere*, "to hang") *ligament.*

At the back of the eye, behind the lens and inside the choroid coat, is the third coat of the eye, the *retina* (Latin *rete*, "a net"). This is a thin membrane in which the fibers of the optic nerve, entering through the walls of the eyeball behind, radiate in all directions. Between the lens and the retina is a clear fluid substance, the *vitreous* (Latin *vitrum*, "glass") *humor.*

Structure of retina. The retina is really an expansion of the optic nerve, with structures built up upon it to receive and transmit the impressions of light, which come from without through the pupil and lens, on to the brain in such a way that we get there an image of the thing before our eyes.

These structures which receive the light impressions are known as the *rods* and *cones.* Over the whole surface of the retina is a layer made up of numerous rodlike cells, with tapering threadlike processes running toward the front of the eye, and of sugarloaf-shaped bodies with short processes, the cones. The processes of both rods and cones give out delicate threads which run to cells deeper in the retina, and these again attach to the fibers of the nerve. The structures of the retina are laid down in eleven layers. The nerve layer is in front. The light passes in through all these structures to the layer of rods and cones. Here the impression is taken and the cell processes set vibrating. This

vibration is transmitted from the rods and cones to the nerve fibers, and thus to the brain.



Section of retina.

In the center of the retina is an oval spot, the *yellow spot.* Here the layers of the retina, except the layer of the rods and

cones, are thin, and the cones are, contrary to the condition elsewhere, thicker than the rods. This is the part of the eye where the image strikes when we look straight at an object so as to get the clearest vision of it.

The blind spot. There is one part of the retina where the optic nerve passes through it from the back to the anterior surface of the retina, where it spreads out. This spot has no rods and cones, and therefore takes no impressions. It is called the blind spot. This spot can be found by the following experiment: Place upon a piece of paper a cross and a round black spot, three inches apart, as upon this page:

Hold the sheet about twelve inches in front of the eyes. Close the left eye and look at the cross with the right; you will see the dot at the same time. Move the sheet slowly toward you, keeping the right eye fixed upon the cross. At a certain distance from the eye the dot will disappear, and will reappear as the sheet is brought still nearer. When the sheet is at the place where the dot cannot be seen, the light from the dot is falling upon the blind spot. When the sheet is farther or nearer, the light is upon the retina to the right or left of this.

Mechanism of sight. The coats of the eye, the sclera and choroid, serve to carry vessels for the nourishment of the retina, and also for protection and for the formation of a chamber for the reception of the light images. The refracting media, —the aqueous humor, the lens, and the vitreous humor,—the cornea, and the accommodation (Latin *accommodo*, "adapt") mechanism of the iris are for the purpose of bringing the rays of light upon the retina in such a way as to form a clear image of the thing seen. The cornea and refracting media of the eye collect the rays of light from the object seen, and

focus these rays upon the retina. In this way an inverted image of the object is formed upon the retina. The lens and other refracting media simply bend the rays of light from the object seen in such a manner that they all fall within the space of the retina, so that, unless it is too near, a very large object can be focused upon the small area of the retina. Light consists of vibrations of the ether. When these waves of vibration strike the convex surface of the refracting media, they are bent inward. The amount of bending depends upon the convexity of the lens. If the object is near the eye, the rays need to be more bent to focus upon the retina; that is, we need a very convex lens. If the object is far away, the rays need less bending and the lens must be less convex. That we can focus both near and far objects perfectly in our eyes is due to the faculty of the eye of changing the convexity of the lens. This is known as accommodation.

The *mechanism of accommodation* is regulated by the action of the ciliary muscles of the lens supports. The lens is an elastic body which tends naturally to take a very convex shape. It is inclosed in a capsule, to which is attached the suspensory ligament. The ligament is so adjusted that when the ciliary muscles of the choroid processes contract, the ligament is slackened and the lens is free to take its natural shape. This occurs when we accommodate the eye to a near object. When the muscles relax, the ligament is drawn tight, pulling on the lens capsule and flattening the lens, so that it is less convex. This occurs when we look at a far object.

Short and long sight. Most people cannot see objects clearly which lie nearer than five inches from the eye. This is because the lens cannot be made convex enough to focus all the rays from such an object upon the retina. The rays from the sides of the object go by. Some people, however, see close objects better than more distant ones. These

are shortsighted people. Their peculiarity is due to the fact that the retina is farther off than normal from the lens, so that near objects can be bent to it. Owing to this distance of retina from lens, these people cannot focus a distant object. No matter how much the lens is flattened it focuses in front of the retina, where the normal retina would be. To correct this difficulty such people have glasses made with a concave lens. This throws the rays outward and causes them to focus farther back.

In a long-sighted person the ball is shorter than the rule, and near objects focus behind the retina. An additional convex lens has to be used to correct this.

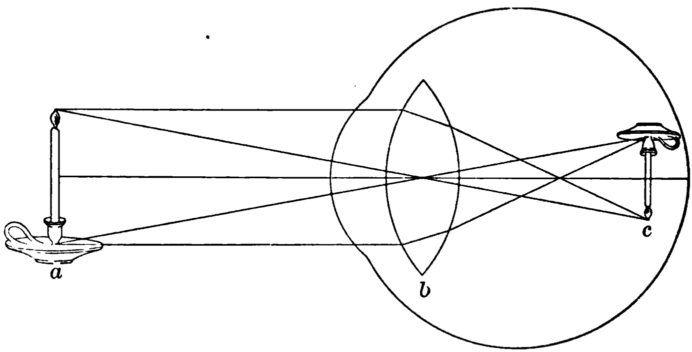


Diagram of refraction.
a, object; *b*, lens; *c*, image upon retina.

Action of the iris. The lens is not a perfect instrument. Some of the rays are brought to a focus in front of most of the rays. To remedy this defect the eye is provided with the iris curtain. This curtain shuts off more or less of these rays which do not focus on the retina, and thus leaves a clear image there. The amount of light which must be cut off differs with the distance of the image. If the image is near, much light is cut off; if distant, little

light. To meet these varying conditions the iris is made to grow larger or smaller, so that when an object is far away the iris is pulled back and the pupil is large, and when the object is near the iris closes and the pupil is small. You can see the pupil change if you watch the eye of some one who is looking at your finger as you draw it gradually away from his face. To change in this way, the iris is provided with a sphincter (Greek *sphiggein*, "to contract") muscle which contracts it, and other muscles which draw it back.

The formation of a clear image in the eye may be illustrated by the following experiment: In a dark room fix a lens a few feet in front of a candle flame. If a sheet of paper is held at the right distance in front of the lens a clear inverted image of the candle flame will appear upon the paper. The paper here represents the retina of the eye, the lens the refracting media. If the candle were held before the eye, the image would appear upon the retina as upon the paper.

Now, if the candle is held nearer the lens, the image upon the paper will grow indistinct. To get a clear image we have to move the paper away from the lens or replace the lens by a stronger, more curved one. In the eye the latter method is adopted; the lens is made more convex by the mechanism of accommodation. If the candle is moved farther from the lens, the paper has to be moved nearer to get the clear image, or the lens made weaker, less curved.

You can demonstrate this action of accommodation in your own eyes by the following experiment: Place two pegs in a board, one about a foot from the end and the other eighteen inches farther away. Close one eye, and with the other look along the board with the pegs nearly in a line. If you look at the farther peg this will be clear and the nearer indistinct. If you accommodate to the nearer, the farther will be indistinct.

Hygiene of the eye. The eye, like all the organs of the body, can be trained by exercise. Constant practice in shooting, in ball playing and tennis, gives a man what is known as a true eye. A trained eye compared with an untrained one is like a high-power microscope compared with one of lower power. And yet the eye is only the instrument; it is the mind that sees. While the more perfect the instrument the more the mind can see, yet a keen mind is necessary to a keen eye.[1]

The eye suffers from improper exercise or overwork, and want of care. A child must hold the book which he is reading at the correct distance from the eye, neither too near nor too far, else he will strain the apparatus of accommodation. He must read with proper light, and with the bright light behind him. Disregard of these precautions may lead to impaired eyesight for life.

In school the desks should be so placed that the light comes from the rear or the side. A cross light which dazzles the eye should be avoided by means of window shades. The pupil must not sit with the head and body bent forward over the desk while reading. Well-printed books with type of good size should be chosen.

At home the child should never read by candlelight or by light from any flame which flickers. Reading in bed while lying upon the back is a bad plan. Reading in the cars, where the book is being constantly jolted, is harmful; it tires the muscles of the eyeball and of accommodation.

Objects which get into the eye should be carefully removed. The eye should not be rubbed in such instances or upon any occasions when it smarts or tingles.

[1] The eye is the most expressive part of the face. However pronounced the smile about the mouth, if it is unaccompanied by a kindly light from the eyes it has an unpleasant effect. So responsive are the muscles about the eyes to the thoughts of the mind that the lines formed there by their habitual position come to show the kind of thoughts that the mind harbors most, and thus character is revealed by the face.

If children are found to be nearsighted or farsighted they should be placed under the direction of an oculist. People may injure themselves by wearing glasses when they do not need them or by wearing improper glasses. They should get their glasses in accordance with the advice of a competent physician.

As people grow old changes occur in the lens which limit its accommodation. It cannot be made so convex as before to accommodate to near objects. When this trouble appears, glasses should be worn fitted to the eyes.

The signs of eye strain are apt to be sharp neuralgic pains about the eyes and a sense of fullness in the eyeballs. When these signs appear regularly after reading the eyes should be examined.[1]

The effect of alcohol upon the eyes is seen in the bloodshot conjunctivæ and relaxed watery lids of topers. Alcohol may cause disease of the retina, with marked disturbance of vision.[2]

Tobacco smoking tends to bring about inflammation of the conjunctivæ and lids by the irritation of the smoke. The absorption of poison from constant smoking may bring on a diseased condition of the retina, resulting in diminution or even loss of vision.

HEARING

Sound is caused by the vibrations of a substance. When a bell rings, the vibrations of the metal set up waves of

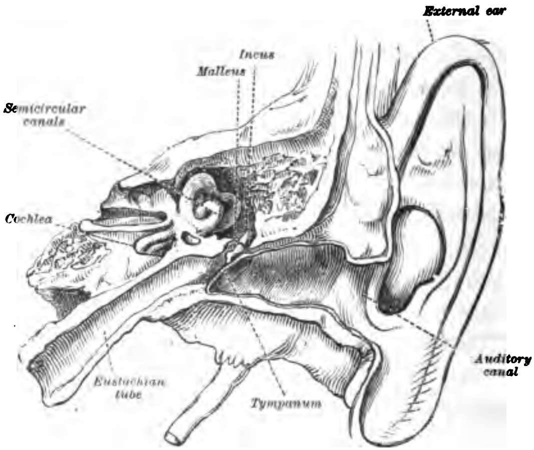
[1] Little children should not be allowed to look at very fine objects with the head down. The use of printed books before a child is eight years old is a menace to the eyes. Students should make it a rule to stop for a few minutes at the end of every hour to rest the eyes. In very close work a stop should be made every ten minutes after a person is thirty years old; a few seconds will suffice.

[2] Drs. Nicol and Mossop of Edinburgh conducted a series of experiments on each other, examining the eye by means of the ophthalmoscope while the system was under the influence of various drugs. They found that the nerves controlling the delicate blood vessels of the retina were paralyzed by a dose of about a tablespoonful of brandy.

vibration in the air, which are transmitted to the ear. When these vibrations in the ear are taken up by the sense organ and converted to nerve impulses, which are carried to the brain by the auditory nerve, we have the sensation of sound. We hear the bell ring.

The organ of hearing is the ear. The *ear* consists of the external ear, the middle ear, and the internal ear.

The *external ear* consists of a cartilage shell covered by connective tissue and skin. This shell collects the sound.



Section of ear, showing auditory canal, middle ear, internal ear, and Eustachian tube.

From this outer shell a canal runs inward into the temporal bone. At the inner end of the canal is a membrane, the tympanum, which stretches across the canal and shuts it off from the middle ear. The canal is lined with skin, and a substance called wax is secreted in it from glands in its walls.

The *middle ear* is a cavity in the temporal bone. The

drum, or *tympanum* (Greek *tumpanom*, "a drum"), shuts it off from the outer ear. From its inner side a tube, the *Eustachian* tube, leads to the upper part of the pharynx. We can feel the air go into the ear by this tube sometimes when we swallow.

In the inner wall are two openings, the *fenestra* (Latin *fenestra*, "window") *ovalis* ("oval") and *fenestra rotunda* ("round"), which lead to the cavity of the inner ear. They are closed each by a membrane.

Stretching from the tympanum to the fenestra ovalis across the middle ear is a chain of three small bones. The first is shaped like a hammer and is called the *malleus* (Latin, "mallet"). The handle of the hammer attaches to the tympanum, the claw to the wall of the cavity, the head to the next bone, the incus.

The *incus* (Latin, "anvil") is anvil-shaped. The head articulates with the hammer, one process with the wall, and one with the third bone, the stapes.

The *stapes* (Latin, "stirrup") is stirrup-shaped. The top of the arch attaches to the incus; the foot plate fits into the fenestra ovalis against the membrane there.

Two muscles attach to these bones—one to the hammer handle, which by contracting tightens the drum of the ear, another to the arch of the stirrup, which tightens the membrane of the fenestra ovalis.

The *internal ear* is a cavity in the temporal bone. It connects with the middle ear by the two fenestra openings, which are covered by membranes. In this cavity lies a membranous sac filled with fluid and floating in fluid, which fills the cavity. The sac is attached to the walls of the cavity in several places. This sac contains the essential organ of hearing, by which the vibration waves of sound are taken up and transmitted to the ear.

The sac, or *membranous labyrinth*, consists of several cham-

bers. The middle chamber, the *vestibule* (Latin *vestibulum*), lies opposite the fenestra ovalis, where the stirrup bone of the middle ear abuts. From the vestibule open three canals, the *semicircular* (Latin *semi*, "half," and *circulare*, "to encircle") *canals*, which are closed tubes circling round and returning to the vestibule again. One canal has a horizontal position, two have a vertical position. At the end of each canal is a bulb attached by fibrous tissue to the bone. At these bulbs, branches of the auditory nerve enter. From another part of the vestibule a tube in the form of a spiral coil with a blind end is given off. This is the *cochlea* (Latin, "snail").

Semicircular canals and cochlea.

The membrane of the ear sac, the vestibule, canals, and cochlea is made up of connective tissue lined within by epithelial cells. In patches over the walls of the canals and cochlea are collections of cells known as the *auditory* (Latin *audire*, "to hear") *epithelium*. The cells which make up these patches are cylindrical and spindle-shaped, and have processes projecting into the lymph which fills the sac. The ends of the auditory nerve, which enter the sac at the bulbs of the canals and in several other places, connect with these cells. A special tract of this auditory epithelium is situated in the cochlea. It is called the *organ of Corti*.

The nerve fibers end here in cells known as hair cells, which are placed in rows beside a central row of rod-shaped cells.

The sac is filled with a fluid called the *endolymph* (Greek *endon*, "within," and Latin *lympha*, "water"). About the sac in the bony cavity is a fluid, the *perilymph* (Greek *peri*, "around"). This perilymph lies against the fenestra ovalis on one side of the cochlea and against the fenestra rotunda upon the other.

Transmission of sound in the ear. The waves of sound are collected by the external ear, pass in through the external canal, and set the tympanum in vibration. This vibration is transmitted by the three bones, the malleus, incus, and stapes, to the fenestra ovalis. Here the vibration is transmitted to the perilymph, and thus to the walls of the vestibule, canals, cochlea, and endolymph. The vibrations of the endolymph agitate the cells of the auditory epithelium, especially the hair cells of the cochlea, and are transmitted by these to the nerve endings, and thus to the brain, where the sensation of sound is aroused.

Character of sound. Sounds differ according to the character of the vibrations which are set up in a body. When a bell is struck the vibrations follow each other at regular intervals, and the sound is called a *musical sound.* When a lot of crockery falls the vibrations are irregular, and we call the sound a *noise.*

Pitch. What is called the pitch of a sound depends upon the number of vibrations in a given time. If the vibrations follow one another slowly the pitch is low; if they follow rapidly the pitch is high. The ear can perceive notes of a pitch so high that the vibrations occur from twenty to thirty thousand in a second, or so low that the vibrations are thirty a second.

Hygiene of the ear. The acuteness of the ear may be trained. The Indian of the forest hears sounds which we cannot hear. The trained musician distinguishes notes and pitch much more accurately than an ordinary person.

No one should ever shout close to a person's ear, or set off a firecracker or pistol near the ear, as the sound may produce serious injury. Hairpins and other articles should not be put into the ears to relieve itching. They inflame the canal and may puncture the drum.

Children not infrequently have so-called gatherings in

the middle ear cavity. This is an inflammation of the membrane of the cavity. The fluid which is exuded by the inflammatory process often bursts the drum and discharges by the outer ear. In babies who are feverish and restless we should always think of this trouble. Where the trouble is suspected a physician should be called at once.

Children with adenoids or large tonsils are apt to have trouble with the ears. These abnormal growths should therefore be removed at an early age.

Tobacco smoking, by inflaming the throat, often causes irritation about the openings of the Eustachian tubes from the ears, thus diminishing the circulation of air in the middle ear and making the part more subject to disease.

The muscle sense is the perception which we have of the position of a limb or a part of the body. The organs and nerve endings of this sense are situated in the muscles and in the tissues about the joints.

The pressure sense is the perception which we have of the weight of an object. The nerve endings in the skin and muscles of the region supporting the weight transmit the impression to the brain.

DEMONSTRATIONS AND EXPERIMENTS

A number of experiments to illustrate the phenomena of the special senses have been given in the course of the chapter.

1. The organs of the sense of touch are very numerous in some parts, as upon the finger tips or upon the end of the tongue. Here you can feel both points of a compass even when they are but an eighth of an inch apart. In other parts, as the back, however, the sense of touch is much less acute. Here the two tips of the compass often feel as one object even when three fourths of an inch apart.

2. Determine the relative sensitiveness to touch of the palm and back of the hand, the forehead, the back of the neck. (Use a hair.)

3. Determine what is the least distance that the two points of a compass may be separated and still recognized as two when applied to the finger tip, the tongue, the back of the neck.

4. Place a drop of vinegar upon the tongue. Note how it starts up the papillæ into prominence.

Note that sugar is tasted best at the front of the tongue; salt or aloes at the back.

5. Hold the nose and close the eyes while some one puts a piece of apple or potato into your mouth. You will be unable to tell which you have received, as the so-called taste of these substances is in reality a sensation of smell.

6. With a common hand lens (a burning glass) throw the image of a window upon a sheet of paper. This represents the mechanism by which the image of an object seen is thrown upon the retina.

7. Look through a pinhole at a bright light with a shade about it. The specks which you will note floating before your vision are made by opaque particles floating about in the vitreous humor in front of the retina.

8. Accommodation. Close one eye. Hold up both forefingers, not exactly in line, one six inches from the open eye, the other about eighteen inches away. Look at the near finger. A clear image of this is obtained, while the farther one is indistinct. Now look at the far finger. This now becomes distinct, while the near one becomes indistinct.

9. Place a watch between the teeth. Note that the ticking is readily heard with both ears closed. The sound is conducted by the solid bone of the jaws.

10. Place the right forefinger in hot water, the left forefinger in cold water. Note the difference in the sensations.

11. Determine which of the following substances stimulate the sense of taste and which that of smell, which are recognized by their taste, which by their odor: sugar, onion, cabbage, dilute ammonia (one drop to six ounces), quinine, salt, vinegar.

12. The formation of an image upon the retina can be illustrated with the eye of a white rabbit.

13. The formation of an image upon the ground glass of a camera, and the influence of focusing upon the clearness of the image, may be demonstrated with a photographic camera.

14. The color vision of the pupils may be tested with different-colored worsteds.

QUESTIONS

I. What is sensation? Through what channels do we become aware of the world about us? Name the special senses. Where are the organs

of touch located? Where is the sense of touch located? How does the knowledge that we are touching anything get to the brain? Where are the organs of the sense of taste? Describe the papillæ of the tongue.

II. Where are the organs of the sense of temperature located? What is the difference between a taste and a flavor? Has an onion any taste? Where are the sense organs of smell? What is the function of the eye? When we get a sight of any object, where do we really see it? Of what use are the eyelids?

III. Why is the eyeball so prominent? Why is it movable? Where are the tears secreted? What is the white of the eye? What in reality is the dark center of the eye which we call the pupil? What is the part of the eye which gives it its color? What object lies at the back of the pupil?

IV. When an object comes before us, what does the eye do? Where is the image of the object cast? When an image strikes the retina, what happens in the brain? Of what use is the lens of the eye? To what part of a photographic camera does the retina correspond?

V. What is the use of the iris? What is meant by the blind spot? How is it arranged that the image of so large an object as a house can be cast upon so small a surface as the retina? What happens to the lens when the object is very near the eye? Very far away? Describe this mechanism of accommodation. How can we avoid straining the eyes?

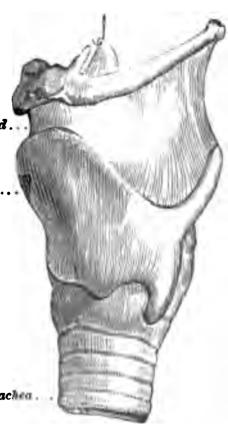
VI. What is sound? Describe the three parts of the ear. Which is the most important part? Trace the sound waves from a bell to the brain. What is the difference between a musical sound and a noise? What is pitch?

CHAPTER XIV

THE VOICE

BY the action of the inspired and expired air in setting up vibration of the folds of membrane in the larynx called the vocal cords, the sounds are produced which we call the *voice.*

The *larynx* consists of a framework of cartilages articulated together to form a chamber in the course of the air tube between the lungs and the nose and mouth. Stretched across this chamber are the vocal cords, and the air passing these cords can be made to vibrate them at will.

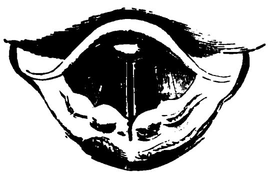


Larynx.

Just above the last incomplete cartilage ring of the trachea we have the first cartilage of the larynx. This is a complete ring, narrow in front, broad behind, like a signet ring. It is called the *cricoid* (Greek *krikos,* "a ring") *cartilage.* Above this is a V-shaped cartilage with broad sides, the *thyroid* (Greek *thureos,* "a shield"). The open part of this cartilage is filled in by the broad posterior part of the cricoid. At the back of the larynx, on each side of the broad part of the cricoid, is a small cartilage, the *aryte-*

noid (Greek *arutaina*, "a pitcher"). Attached to the top of the thyroid is the epiglottis, which closes the entrance between the larynx and pharynx. These and several smaller cartilages, joined together by connective tissue and muscles, make up the larynx.

The inside of the chamber is lined with a mucous membrane continuous with that of the pharynx above. Running across the tube from the arytenoids at the back to the thyroid at the front are two bands of elastic tissue covered by the epithelium of the larynx. These are the *vocal* (Latin *vox*, "voice") *cords*. Through the V-shaped interval between these cords, narrow in front, broad behind, the air passes.



Vocal cords.

When the cords are relaxed, the air passes by freely and does not cause them to vibrate; but if the posterior ends are drawn together, the interval between the cords is reduced to a narrow slit, and the air passing through sets up vibrations in them, producing sound. This is what occurs in voice.

Mechanism of voice. By the action of muscles which attach to the cartilages and move them upon one another, the posterior ends of the cords are brought together. The cords at the same time are tightened by another set of muscles. Then the air pressed forcibly between the cords causes them to vibrate.

In accordance with the action of these muscles the tension of the cords is varied, and consequently the pitch of the sound is produced. A low voice sound means a looser cord, a high sound a tighter.[1]

[1] In the production of a high-pitched sound the whole larynx is raised. This can be demonstrated by placing the fingers upon the throat when the sound is made. In the production of low tones the air in the chest is set in vibration. You can feel with the hand the thrill of this chest vibration when a low tone is made.

The difference in the character of voices depends upon the differences in the shape of the larynx. Thus, a woman's larynx is smaller and the cords are shorter than a man's.

Speech. Speech is produced by modifying, by the shape of the pharynx and mouth cavities, the voice formed in the larynx. The mouth cavity is a sounding box. By the action of the tongue and lips the cavity may be varied in size and shape, and according to this variation different sounds are produced. Thus, to make the sound of the long *a* the mouth is opened wide, the lips drawn back. To make the sound of the *o* the lips are protruded and the cavity of the mouth made long.

The sounds of some consonants are regulated by the lips, as *p*, *b*. These are called *labials*. The consonants *t*, *d* are made by placing the tongue against the teeth. They are called *dentals*. The consonants *k* and *g* are formed in the throat by the root of the tongue and soft palate. They are called *gutturals*.

Hygiene of the voice. Much attention should be directed to the training of the voice. A soft, full voice with musical sounds should be cultivated. A rough voice, or a nasal tone which appears to come from the head, produces an unfavorable impression.[1]

DEMONSTRATIONS

1. A very good illustration of the principle of the action of the vocal bands in the production of the voice may be given by means of a piece of bamboo or any hollow wooden tube and a strip of rubber about an inch or an inch and a half wide, cut from the pure sheet rubber used by dentists.

[1] In impatience or anger the voice rises, betraying the loss of temper or self-control. Americans have a tendency to a high tone of voice, owing probably to the high nervous tension developed by our active business enterprises. It is interpreted abroad as an indication of our crudity as a nation. Thus the term "the American voice" is a kind of national reproach, which we should seek to remedy by cultivating purer and lower tones, more quiet manners, and self-poise.

One end of the tube is to be cut sloping in two directions, and the strip of sheet rubber is then wrapped around the tube so as to leave a narrow slit terminating at the upper corners of the tube.

By blowing into the other end of the tube the edges of the rubber bands will be set in vibration, and by touching the vibrating membrane at different points, so as to check its movements, it may be shown that the pitch of the note emitted depends upon the length and breadth of the vibrating portion of the vocal bands.—Dr. H. P. Bowditch.

2. Pinch the nose and speak some words like "something" or "pudding." This illustrates the usefulness of the nasal cavity as a resonant cavity in speech.

3. The effect of a resonance chamber, as the mouth, can be demonstrated by striking a tuning fork and holding it before the mouth and before several resonance chambers.

4. The relation of pitch to rapidity of vibration, and of volume of sound to extent of vibration, can be illustrated by a violin, or a piece of catgut which is stretched tightly between two fixed points.

QUESTIONS

What is the organ of the voice? How are the voice sounds produced? How are the voice sounds modified into speech?

CHAPTER XV

FERMENTS AND FERMENTATION—THEIR PLACE IN NATURE. BACTERIA AND THEIR CONNECTION WITH DISEASE

> With Earth's first Clay They did the Last Man knead,
> And there of the Last Harvest sow'd the Seed:
> And the first Morning of Creation wrote
> What the Last Dawn of Destiny shall read.

The indestructibility of matter. Everything in the world is in a constant process of change. Mountains which to-day lift their snowcapped peaks among the clouds were once covered by the sea. Plains and valleys once spread with forests and inhabited by men and beasts are now deep beneath the ocean, the abode of the seaweeds and shellfish. Once stately cities, the abodes of wealth and power, now lie buried beneath the soil piled upon them from their own ruins and the ceaseless labor of the earthworms. The water which yesterday fell as rain is to-day a part of the leaf of some plant or the blood of some animal, and to-morrow will rise again to the clouds. The vegetables or fruit which we gather for food will be built up into bone and muscle, and in turn be burned until their elements are scattered again to the air and the soil.

Everything is continuously building up and crumbling again. The elements of which all things are composed, such as the carbon, oxygen, nitrogen, iron, calcium, and hydrogen,

alone of all materials upon the earth, are never destroyed; but, forever driven by the ceaseless force which in a thousand forms everywhere pervades the universe, these atoms[1] continue their unending journey through the realm of nature, now taken from the air to form a part of the fiber of some moss, now lying for thousands of years stored in coal beneath the earth's surface, now restored to the air and soil by the burning of this coal; to-day a part of your bones or brain, to-morrow in the petal of some flower or the water of some woodland fountain.

In the mineral world, the rocks and sands, these changes occur slowly during years and centuries; but in the world of living things, the plants and animals, the changes are very rapid and complete.

Each year millions of plants which grow in the spring die and crumble away in the summer and autumn, and thousands of men and beasts which have been built up through long years are dying and their bodies returning to the dust from which they came. Within these living bodies of animals new tissues are constantly being built and burned from day to day.

A part of this process of change which goes on in the world of living things has been minutely described. We have seen how the carbon, nitrogen, oxygen, hydrogen, and other elements in the air and soil and water are taken up by the plants and built into wheat or potato or some fruit; also how these plant substances are built up to bone and flesh in the animal body; finally how some of these body substances are broken up again by burning in the body, and distributed back to the air and soil. But we have not yet learned how these full-grown plants and animal bodies, with their fiber and leaf and bone and flesh, are reduced

[1] The word "atom" (Greek *a*, privative, and *temno*, "I cut"— not to be cut) is used to describe the forms of matter which cannot be further divided.

again, when they die, to carbon, nitrogen, oxygen, and so forth. This has to be done, otherwise the supply of these elements in the air and soil would soon become all stored up in existing plants and animals, and none be left for the building of new ones or the repair of the old.

Ferments and fermentation. To do this work nature provides certain agents known as *ferments.* These ferments which play this important rôle in the scheme of nature are minute living organisms, so small that they can be seen only with the aid of a powerful magnifying lens. Because they are bodies possessing life they are called *organized ferments.*

One of these ferments, the yeast plant, has already been described in Chapter VII. (see also pp. 274–276). Another class consists of the molds which you have often seen growing upon old fruit or grain. A third class of organized ferments is that of the *bacteria.*

The process by which these ferments act in fulfilling their work in the scheme of nature is known as *fermentation* (Latin *fermentum,* "leaven"). The decay of fruit or vegetables, the putrefaction (Latin *putris,* "rotten," and *facere,* "to make") of meat, the souring of milk, the decomposition of sugar to alcohol and carbon dioxide, the conversion of alcohol to acetic acid, are all examples of fermentation.

The process is essentially one of decomposition (Latin *de,* "from," and *componere,* "to place together"—breaking apart). As we have explained in a previous chapter, the organic substances which compose the tissues of animals or plants are compound substances. They are made up of simpler chemical substances (elements) bound together. These compound substances the ferments attack, feeding upon them and breaking the bonds which hold them together, so that they fall to pieces.

The method which the ferment adopts in separating the

compound into its constituents is too complex to be described here. It works in quite a different manner from that in which an ax splits a piece of wood; for the ax simply gives us two smaller pieces of the same substance, while the ferment gives us two or more new substances. But the process is one of splitting up in both cases. And when the ferment has split one molecule it still remains to split more. It is not used up in the process, as is an acid which splits up a salt by chemical combination. Thus, in cider in which the sugar has been fermented, the yeast ferments can still be found at the bottom of the liquid, ready for action upon a new mixture.

(**Unorganized ferments.** In addition to these organized ferments there is another class of ferments, represented by the digestive ferments, ptyalin, pepsin, rennin, and so forth, already mentioned, which are simple chemical substances, not living organisms. In contradistinction to the organized ferments these non-living agents are called unorganized ferments. They are produced by the activity of gland cells, just as many organic substances, proteids, sugars, and glycogen, are produced. Their method of action is similar to that of the organized ferments.[1])

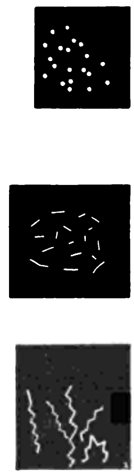
In addition to their work in assisting in the decomposition of the dead organic matter, these organized ferments have another action which makes them of special interest to us. They cause certain diseases in men and animals known as the *infectious* (Latin *inficere*, "to infect, corrupt") *diseases.* These diseases are due to certain of these low forms of organisms which lodge in the body and set up processes of fermentation there similar to those which are set up in the dead organic matter; and most of them are due to the special class of ferment known as the *bacteria*

[1] The fermentative action of the organized ferments is probably due to an unorganized ferment, which is secreted by the ferment organism which is a living cell.

(Greek *bakterion*, "a little staff"). This name was given because the first bacteria found were the rod-shaped forms known as bacilli.

Bacteria. Bacteria are minute vegetable organisms, so small that they can be seen only by the aid of a powerful magnifying lens. You can gain some idea of their size from the fact that thousands of them could find lodgment upon the head of a pin. Some of them are shaped like round balls, some like little rods, some like spiral threads (Experiment 6, p. 275).

These organisms are alive and grow and multiply. Many of them are everywhere about us, in the air and soil and water, and within our own bodies. Others, like most of those bacteria which cause special diseases, as typhoid fever or smallpox, are not generally distributed, but are found only in regions where these diseases have been, or in substances which have come from such regions.



Bacteria.

The manner of action of bacteria is that of fermentation, described on page 267 and also in Chapter VII.

When the bacteria act upon the dead plants or dead animal tissues lying about on the ground, they break up these substances into simpler substances. So also when the bacteria of disease enter and effect a lodgment in our bodies, they break down our tissues in the same manner.

Some of the common diseases caused by these bacteria acting in this way are diphtheria, consumption, scarlet fever, measles, whooping cough, typhoid fever, smallpox, and probably influenza.

In diphtheria (Greek *diphthera*, "parchment"—membranes

resembling parchment are formed in the throat in this disease), for instance, the little rod-shaped bacilli which cause this disease lodge in the membrane of the pharynx or larynx, and feeding upon the body substances, grow and multiply. Thus feeding, they irritate and decompose the tissues and set up inflammation and necrosis (that is, death of the tissue cells) therein, so that the membrane of the throat becomes swollen and disintegrated. The throat becomes very sore, and the passages are often obstructed by the inflammatory products formed. At the same time, in thus feeding upon and disintegrating the tissues, the bacteria produce or bring about the production of poisonous substances (toxines), which are absorbed into the system and make the patient very ill with fever, headache, nausea, and other symptoms.

All these processes, the inflammation in the throat and the absorption of the poison, may bring about the death of the patient. But if he is strong, in time his body will begin to produce a substance which offsets the action of the diphtheria poison and kills the bacteria in the throat. This antidote is called an *antitoxine* (Greek *anti*, "against," and *toxikon*, "poison"). When this is formed in sufficient amount, the patient begins to get well. Often, but not always, the power of keeping or forming this antitoxine remains thereafter with the patient, so that he cannot have diphtheria again. This condition is called *immunity* (Latin *munire*, "to fortify").

Now, out of all this study of diphtheria and the bacteria which cause it, some very important results have come. Men have learned how to compel these bacteria to produce this antitoxine for them in animals, as horses, and so to-day when a patient has diphtheria we do not have to watch him die in spite of our care, or to wait a week or a month until his own cells form antitoxine enough to stop his disease, but we can

put some of this antitoxine which has been prepared from horses into him, and cure him within a few days.

All the infectious diseases are caused in a similar manner by their special organisms, and perhaps by studying these bacteria we shall be able to compel them to provide antitoxine for us, as we have the diphtheria bacillus, or to produce immunity, as we have the cowpox organism.[1] But whether we obtain this end or not, we have by a study of their habits learned a great deal which will help us in preventing (Latin prefix *pre*, and *venire*, "to come"—to come in advance) the diseases which they cause.

Some of the facts concerning the habits of bacteria are of interest in connection with some of the common practical customs of our daily life. For instance, we find that many bacteria are more active in warm temperature than in cold. This fact explains to us why meat is harder to keep in summer than in winter, and teaches us the reason for the use of ice and refrigerators for keeping milk and meat.

If the action of ferments is absent, some foods will keep for an indefinite period. We find that freezing stops the action of the ferments; therefore we freeze our meat when we wish to keep it for a long time. Much of the meat shipped across the ocean is treated in this way. Such meat will keep as long as it is frozen. The meat upon a mammoth which was found frozen in northern Russia, where the animal had died thousands of years ago, was so fresh that the dogs ate it.

Cooking also kills the bacteria in food and stops all fermentation for the time. In canning food the bacteria are first killed by cooking or heating the food. The food is then closed in cans, where no new bacteria can get to it, and thus keeps (Experiments 5 and 6, p. 275).

Most ferments need water for their life and activity. Drying meat rapidly will therefore keep it, as the bacteria cannot act without the moisture. This is a common method of keeping meat in warm countries.

Making fruit into preserves also keeps it in the same way, as the sugary syrup which is formed has depleted the substance of the water.

Study of bacteria in the infectious diseases. In studying these bacteria of disease we find that they pass from the

[1] This is the organism used in vaccination against smallpox.

body of the sick person in the excreta: the diphtheria and the tuberculosis organism in the exudations from the mouth and throat and nose, the typhoid organism in the fæces, the scarlet fever organism probably in the scales of skin which come away. The bacteria which are scattered in these ways can live for a long time in the air or soil, float about in dust, and then if they happen to get into another person's body can cause the same disease there.

The knowledge of these facts should lead us to be very careful of the disposal of excreta and of all materials which have been in contact with a sick person. They should, if possible, be subjected to some treatment which kills the bacteria in them. Such treatment is known as disinfection (Latin *dis*, privative prefix, and *inficere*, "to corrupt"—to remove corruption).

Disinfection. The disinfection of any substance can be accomplished in various ways. One method of disinfection is burning. This method should be applied to all the cloths upon which a patient with phthisis or diphtheria expectorates (Latin *ex*, "from," and *pectus*, "the breast"). Another method is steaming or placing in boiling water and boiling for twenty minutes. The prolonged high temperature kills the bacteria (Experiment 6, p. 275). This method may be applied to the clothes and bedding of any person ill with an infectious disease. A third method of disinfection is washing or mixing with chemical substances which kill the bacteria.

Among these substances the most important are corrosive sublimate, carbolic acid, chlorinated lime, formaldehyde (formalin), sulphur. These substances are widely used for disinfection. Thus, the fecal discharge of a typhoid patient should be thoroughly mixed with one ounce of chlorinated lime before being disposed of. Articles from the room of the sick person which cannot be boiled or steamed

may be washed with corrosive sublimate solution (1 part to 1,000) or carbolic acid (1 part to 20).

The room itself and the furniture in it may be disinfected by filling the room for twenty-four hours or more with formaldehyde gas or sulphur fumes.[1]

Contagion (Latin *contingere*, "to affect by contact"). The knowledge of the fact that diseases may be carried from one person to another by the excreta, by articles which have been in contact with the sick person, by people who have been with the patient, and by means of the air, teaches us to be careful not only in dealing with patients suffering from severe infectious diseases, to isolate them and disinfect all things in contact with them, but also to exert the utmost care in regard to our ordinary habits of life. People apparently in good health may have disease germs about them which if conveyed to another may give the latter disease. The air and soil about us contain many germs which are capable of causing disease if they get a chance to enter the body, as in an open wound. It must be our care to diminish as much as possible by good habits of hygiene these opportunities for infection.

We must never take into our mouths any article which has been in the mouth of another without first washing it. Penholders and pencils in common use in schools should be placed in disinfectant solutions after use.

When we have coughs we must never expectorate upon the sidewalk or floor, but into a cloth which can be boiled or burned.

We must keep clean, for filth is a great breeding ground of disease.

[1] Mode of fumigation (Latin *fumigare*, "to smoke") with formaldehyde of room where a patient has been ill with an infectious disease:

Hang up and loosely spread out clothing, bedding, and rugs, leaving chairs and bedstead uncovered. Spray everything thoroughly with water. Close tightly all openings to the room; then distill through keyhole five ounces of formaldehyde solution for every ten square feet of space, or burn in the room paraform pastils — one sixty-grain pastil for every hundred cubic feet of space.

Whenever we get an open wound we must wash it carefully.

Most of all, we must keep ourselves in good health and avoid all undue exposure to cold or poisoning or to disease in others, for a healthy condition of the body is the first preventive of disease.

STUDY OF ORGANIZED FERMENTS

YEAST

1. Add a little baker's yeast to a five per cent solution of grape sugar. Place in a wide-mouthed, loosely stoppered bottle, in a temperature from 70° to 95° F.

After a few hours take up some of the sediment with a pipette, and place upon a glass slide. Cover with a cover slip and examine with a microscope (three hundred to five hundred diameters).

Note the yeast cells.

Note the younger cells budding from the parent cells.

YEAST FERMENTATION

2. Observe the changes which occur in the appearance of a mixture of yeast and sugar during the day.

The increased amount of sediment and scum is due in great part to the multiplication of yeast cells.

Note the bubbles rising through the liquid. These are bubbles of carbon dioxide gas, formed in the splitting up of the sugar to carbon dioxide and alcohol.

Note the change in the odor of the liquid.

3. Pass a U tube through the cork of the bottle, so that the end within the bottle lies above the mixture. Place the other end in some limewater in a test tube. Note the change which occurs in the limewater. This is the same change, due to the same agent, which you have noted in Experiment 6, page 34, and Experiment 2, page 194.

The alcohol which is formed by the yeast remains in the mixture. It can be separated by distillation.

HABITS OF YEAST—EFFECT OF COLD UPON ACTIVITY OF CELLS

4. Add some yeast to a grape-sugar mixture. Place in the ice chest. Observe the mixture from time to time, and compare its condition with that of the mixture used in Experiment 1.

What conclusion can you draw from the result of this experiment?

5. Place some yeast in a sugar mixture. Boil mixture. Then set aside in a warm place, as in Experiment 1. Note results during the day as compared with those in Experiment 1. Draw conclusions.

DEMONSTRATION OF BACTERIA

6. Boil some finely chopped hay in water for ten minutes (not longer). Take a little of the scum which floats upon the surface of the cooled mixture upon the end of a glass rod which has previously been passed through a flame, and place it upon the surface of an agar slant culture. (Agar is a substance which serves as food for bacteria. If some of it is kept in a stoppered test tube it can be used at any time to grow the bacteria upon. Get some agar tubes with water of condensation present.) Keep the agar tube upon which the hay scum has been placed stoppered with cotton in a warm place. The next day a white creamy substance will appear upon the surface of the agar. This white substance consists of millions of little bacteria which are growing rapidly upon the agar. This bacterium is known as the hay bacillus, or *Bacillus subtilis*. These bacilli are present upon hay and collect in the scum upon boiling. The few of these contained on the end of the rod produce the myriads which form the white growth upon the agar.

Take some of the water of condensation from the tube and place upon a glass slide. Cover with a cover slip and examine with a high-power lens. The bacilli, which look like rods, will be seen. They are motile and can be seen to move.

If some of the white growth or this water of condensation is placed upon a second clean agar culture, a similar growth will appear.

Effect of high temperature upon bacteria. If the culture tube containing the bacilli is boiled for half an hour and then some of the growth is transplanted, the bacilli will fail to grow upon the new tube, as they have been killed by the prolonged high temperature.

QUESTIONS

I. Is any form of matter or force in the world ever really lost? What becomes of the elements of the matter which makes up the leaves and the flowers when these die and decay? What agents bring about this disintegration and decay of organic matter? What are bacteria? Are they useful? When do these small organisms do harm? Describe their growth upon and in the matter of living bodies.

II. What class of diseases do they cause? How can we protect ourselves against these diseases? Is vaccination a good thing? Why? What is immunity? What is antitoxine? What is disinfection? What is isolation?

CHAPTER XVI

DISEASE — ITS PREVENTION AND ITS CARE

AS we have learned, disease is some disorder of the structures or the functions of the body. The causes of these disorders are very numerous.

Disease may arise from some mechanical injury from without. Such disorders are fractures and contusions or sprains resulting from blows or falls, or open sores resulting from cuts or bullet wounds.

It may arise from exposure to cold and wet. Such disorders are colds and inflammation of the throat or of the lungs. Exposure of this kind is a very important element in the contraction of many diseases of serious nature, as pneumonia, sore throat, rheumatism (Greek *rheuma*, "a flowing"—exudation), nephritis (Greek *nephros*, "kidney"), consumption (Latin *consumere*, "to waste away"), influenza (grippe). The exposure to cold or damp is often not the real cause of these diseases, but it reduces the vitality (Latin *vita*, "life") of the body and its power of resistance, and so gives the disease a chance to gain a foothold. Thus, pneumonia is caused by a minute live organism belonging to the class of bacteria already described. This germ is everywhere about us in the air, even in our mouths and throats. While the body is in a state of health it cannot gain a foothold in it, but the moment the vitality of the body is reduced by cold

or some other cause this little enemy may find its chance and invade the lungs, causing an inflammation there which is called pneumonia (Greek *pneumon*, "lung").

Animal and vegetable parasites, as the bacteria, are a common cause of disease.

The bacteria of some diseases, like those of pneumonia, are everywhere about us in the air and soil. Our only method of preventing these diseases is therefore to keep our bodies in perfect health, or when some disorder, as a cold or a wound, arises in spite of our precautions, to use extra care against the invasion of the disease germs.

Thus, if we receive a cut we can take great care to wash it thoroughly and to cover it, so that the germs which may be in the air or on objects which we may touch may gain no entrance; or we can even apply to the wounds the substances known as antiseptics (Greek *anti*, "against," and *sepo*, "putrefy") or disinfectants, which destroy these germs.

The bacteria of many of these diseases, however, as typhoid fever and smallpox, do not live generally in the air and soil about us. They get to us only by being carried from some other person suffering from the disease. The observance of the ordinary rules of hygiene is not the sole means of preventing these diseases. We can aid in their prevention by keeping away from persons suffering from them, or by ourselves keeping away from other people if we are suffering from these diseases or have been exposed to them; for the germs of some of these diseases, as scarlet fever, may be carried from one person to another on the clothes of one who has seen the sick person.

Other general causes of disease are improper feeding, overwork, taking insufficient rest, or the taking of substances which poison the body, such as alcohol, tobacco, opium, decayed meats, or arsenic. These causes themselves may give rise to disorder, or they may, like exposure to cold

and wet, reduce the vitality of the body, and so offer a chance for the contraction of infectious or other diseases. Thus, people who are overworked or underfed are more apt to contract influenza or septicæmia when exposed to it. Alcohol drinkers are more prone to contract diseases of the throat and lungs and heart than abstainers.

GENERAL PRINCIPLES OF PREVENTION OF DISEASE

The first preventive against all disease is the observance of the laws of health. The knowledge of these laws is obtained by the study of the body.

The rules of living which you have learned from this study, in brief, are: to eat plenty of good food; to observe regularity in meals, in work, in sleep; to take plenty of out-of-door exercise; to avoid all substances which can injure the body; to avoid all undue exposure to cold or wet or conditions of disease.

The second method of prevention of disease is to stop the carrying of disease germs from one person to another. This work in great part is the office of the boards of health and the physicians of our communities. Physicians and scientists have been studying for years the nature of diseases which are due to these bacterial germs. As a result of the knowledge gained by these studies, they are now able to do much toward the prevention of many of them.

The first method which they use is that of *isolation*. When a physician discovers that his patient has scarlet fever or diphtheria, he has him separated from other people as much as possible, so that the bacteria from his disease may not infect any one else. A sign is placed upon the house, to keep people from it. The other children of the family are kept from school, that they may not carry the disease germs to the children in school.

Another method which is used to prevent the spread of disease is *disinfection.* This method and the means of its application have been described in the chapter upon bacteria and the infectious diseases.

A third method of the prevention of these diseases is by the production of *immunity.* Thus, people are made immune to smallpox by the process known as vaccination (Latin *vacca,* "a cow"—serum from a cow with cowpox is used in vaccination). By having all children vaccinated before entering school it has been found possible practically to stamp out this disease from our communities.

Children can also be made immune to diphtheria by treating them with the substance known as diphtheria antitoxine.

It is the duty of each one of us to assist in every way possible the boards of health and physicians in the work of preventing and restricting disease.

The following directions for the prevention and restriction of dangerous communicable diseases are issued by the Michigan Board of Health for the use of teachers of that State in giving instructions to the children in the schools.

DANGEROUS COMMUNICABLE DISEASES IN THE ORDER OF THEIR IMPORTANCE, MODES BY WHICH THEY ARE SPREAD, AND BEST METHODS FOR THEIR RESTRICTION AND PREVENTION

Consumption is now known to be a communicable disease. It is spread by the dust of dried sputa, and also by milk and meat of tuberculous animals. The most important measure for the restriction of consumption is the disinfection or destruction of all sputa of every consumptive person.

It is best that all persons who have a cough should carry small pieces of cloth (each just large enough properly to receive one sputum), and paraffined paper envelopes or wrappers in which the cloth, as soon as once used, may be put and securely inclosed, and, with its envelope, burned on the first opportunity.

Pneumonia is spread by a germ which is in the sputum of those who have the disease (and of some who do not have the disease, unless, possibly, after exposure to the inhalation of cold air). Care should always be taken to destroy or disinfect all sputa of those who have pneumonia.

Influenza is now believed to be spread by a germ which finds its way from infected handkerchiefs and other articles and places into the nose, throat, and air passages of persons susceptible to this disease. The measures for its restriction are therefore obvious—isolation and disinfection.

Diphtheria is spread by the sputa, saliva, and whatever comes from the throat and mouth of the patient, and by the dust which results from the drying of such saliva. The germs of diphtheria sometimes remain in the throat weeks after apparent complete recovery. For its restriction and prevention, isolation and disinfection are the important measures —isolation of every infected person and thing, and complete disinfection.

Typhoid fever. Unlike typhus fever, typhoid fever is not so often contracted directly from the sick person, but usually from the discharges from the bowels and bladder of the sick person. These always should be properly disinfected. Undisinfected discharges, if dried and formed into dust, may spread the disease through the air. The chief source of danger, however, is believed to be drinking water contaminated by sewage or leachings from privies, etc. The germs permeate the entire body of an infected person, and sometimes are found some time after apparent recovery. The germs of typhoid fever are not always killed by freezing, but are killed by boiling. All suspected water should be boiled.

Scarlet fever. The germ of scarlet fever is not yet identified; but that there is a germ seems to be proved by the well-known communicability of the disease from person to person. It is spread by the discharges from the nose, mouth, and throat, and probably also by the minute scales which are thrown off from the surfaces of the body. Isolation and disinfection are the measures by which this disease is restricted.

Measles is spread from person to person, directly and indirectly. Isolation and disinfection should be enforced.

Smallpox. Smallpox is a contagious disease; it spreads by means of particles given off from the surfaces of the body. By vaccination and revaccination smallpox may be and should be almost wholly prevented. One vaccination or once having smallpox does not protect for life. Revaccination should be had once in about five years, also whenever small-

pox is prevalent, and certainly immediately after one has been exposed to the disease.

Cholera is spread in much the same way as is typhoid fever. The same precautions recommended to prevent the spreading of typhoid fever should be taken as soon as cholera appears or threatens.

WHAT TO DO UNTIL THE PHYSICIAN COMES

Everybody should have some general knowledge of the care of illness, of wounds and injuries, so that he may assist the physician or act in his place in emergencies.

There are many slight indispositions or injuries for which there is no need of sending for a physician. Thus, if a person has a cold in the head, he can often give it all the care it needs by avoiding hot rooms and drafts, by staying in at night, going out in the daytime for vigorous exercise, and perhaps applying vaseline regularly for a day or two to his nostrils. If he has an indigestion he can help it by being careful to eat only good mild foods, as milk, soft eggs, toast, or well-cooked beef or chicken, for a few days. If he receives a slight cut from a knife, or a bruise from a fall, he can care for it himself.

Even in cases of more severe illness or injury it is almost always possible to do something to help the sufferer before the physician arrives, if you only know how to set about it. In many accidents, such as a lacerated artery or suffocation from drowning, it is often necessary to act before the arrival of the physician to save the life of the patient.

The instructions for action in these emergencies given here are very brief, so that they may be easily carried in the memory.

Cuts and lacerated wounds. Where a cut is made with a sharp instrument it bleeds freely. If such a cut is small it is sufficient to bind it firmly in a bandage so that the two edges of the wound are brought together. Healing will take

place in a short time. Where the bleeding is not free, or where the instrument which made the cut is dirty, it is well to wash the wound thoroughly with an antiseptic solution. Such a solution may be made by putting a seven-grain tablet of corrosive sublimate into a quart of hot water. All lacerated wounds, or those made by tin cans, rusty nails, or glass, should be so washed before they are bound up. Where the cuts are large or deep, it is frequently necessary to stitch together the edges of the wound. When a wound heals promptly it leaves no scar. When there is loss of tissue, so that the wound has to heal from the bottom upward, a scar is left.

If the wound severs a large blood vessel the bleeding is more difficult to control. This is especially true if the vessel is an artery. You can always tell when the cut vessel is an artery by the fact that the blood leaps in spurts from the wound and is of a bright-red color. The blood from a vein flows in a steady stream and is of darker color.

Where an artery is bleeding it is necessary to apply some pressure to the vessel between the point of injury and the heart. Thus, if the cut be in the leg or arm, seize the limb high up as firmly as possible in the hands until a large (one-half inch) cord or knotted handkerchief can be twisted round it. The cord can be made to press very tightly by twisting it with a stick. A half-inch soft rubber tube makes the best band of this kind. Often it is necessary to place a pad of cloth beneath the band over the artery, so as to obtain a direct pressure. A physician should be sent for at once in all such cases. Where the edges of cuts or wounds are much swollen and painful during the period of healing, frequent applications of hot-water compresses will give much relief and hasten resolution.

A bruise or contusion is an injury to the soft parts of the body. Frequently there is escape of blood beneath the skin,

causing a black-and-blue spot. The best treatment for a bruise is frequent applications of very hot compresses. This eases the pain and hastens resolution (Latin *re*, "again," and *solvere*, "to dissolve"—removal or disappearance of disease). Bathing in witch-hazel often gives relief. Applications of ice or ice-water compresses are sometimes useful where there is much inflammation of the tissues.

Burns and scalds. These are very painful and oftentimes very serious injuries. Where the burn is due to heat the part must be covered with soft linen cloths upon which some aseptic soothing ointment, as boracic acid ointment or carbolized vaseline, has been freely spread. Where the skin is unbroken, great care should be taken to keep it so. In such cases the burn may be covered with baking soda. Cover or bind up the part in such a manner as to avoid friction. Where the burn is due to acids, the part must be washed with an alkaline fluid, as diluted solutions of ammonia or soda. If due to alkalis, as lime or potash, wash the part in vinegar and water, or dilute acetic acid.

Fire. When the clothing catches fire, the person should be thrown to the ground and enveloped in a rug or coat to smother the flames.

Frostbites. When the ears or nose or toes or fingers are frost-bitten, they should be rubbed in snow or cold water until the circulation of the parts is restored. No warm air or warm applications should be allowed to strike the parts until the sense of feeling has returned. They should then be protected as in cases of burns and bruises.

Sprains. These injuries are very painful. The joint should be immersed in very hot water as soon as possible, and kept there until pain is relieved. The part or limb should afterwards be kept in a horizontal position and protected from pressure. The injured joint should be carefully massaged once or twice a day from the very start. This hastens the

resolution of the swelling and the cure, for the parts regain their tone more quickly under mild use. This active treatment is much superior to the old method of keeping the joints immovable in bandages or plaster. By this treatment the use of the part may be regained in one or two weeks.

Dislocation. When a joint is dislocated the part should be supported until a physician arrives.

Fracture. When a bone is broken the part or limb should be bound up in such a manner as to prevent all motion of the injured bone, and a physician sent for. If the part be supported by splints the patient may be carried to his home without danger. If the injury is to the arm, place it in a sling after the splints are applied, as the dependent position increases the swelling and pain. Barrel staves, pasteboard, or even an umbrella or cane may be so bound to a limb as to serve for a temporary splint.

Bleeding from the nose. This is a frequent occurrence. The loss of a little blood in this way does no harm to a healthy person. To control the bleeding, the patient should sit upright, breathe quietly through the nose, and avoid blowing it. If the bleeding does not soon cease, wrap a cloth dipped in cold water about the neck, and hold the nostrils with the thumb pressed upward upon the upper lip. It may be necessary to insert cotton plugs into the nostrils. *Insufflation* (Latin *in*, "in," and *sufflare*, "to blow up") of powdered alum into the deep nostril may hasten matters, but is rarely necessary.

Bleeding from the lungs or stomach is a serious matter. If blood is coughed up or vomited the patient should be kept perfectly quiet upon the back, and a physician summoned at once. Ice may be freely eaten, but no other substances given by mouth until the physician arrives. Above all, no alcoholic liquors, the so-called stimulants, should be given.

Foreign bodies in the throat. Fishbones and particles of food sometimes stick in the throat. They may be removed by coughing and by slapping the patient on the back, or they may be reached from above by forceps. If they cause trouble with breathing, immediate aid should be summoned. When foreign bodies, as coins, are swallowed, it is best to eat plenty of food to surround them and carry them onward.

Foreign bodies, as buttons or peas, which have been inserted into one nostril by children can often be dislodged by closing the other nostril and blowing forcibly into the child's mouth.

Foreign bodies in the ear are often difficult to remove. The removal may be accomplished by syringing out the canal. If insects get into the ear, they can often be coaxed out by holding a light close to the ear. If this fails, a little oil or glycerin as hot as can be borne should be dropped into the canal, and the head turned to one side to allow it to run out again.

Dog bites. The bite of a healthy dog should be treated like any unclean wound, that is, washed with an antiseptic solution and dressed. If there is probability that the dog is mad, active treatment should be at once applied. If the bite is in a limb, the limb above the wound should be ligatured. The wound should be wiped out thoroughly and the surface burned with silver caustic or a red-hot poker. The part is then poulticed. Where the case is taken in time the patient can escape hydrophobia by being subjected to the Pasteur treatment, even though the virus from the dog has entered the system.

Fainting. Fainting is a condition of unconsciousness due to disturbance of the circulation following weakness or to some sudden emotion or pain. A fainting person must be laid flat on the back, with the hips slightly elevated. Give plenty of fresh air, loosen the clothing, throw cold water

upon the face and chest. The holding of ammonia (smelling salts) to the nose may help revive the patient.

Fits. Fits are, as a rule, spasms in which the person trembles and shakes all over and becomes unconscious. They may be a symptom of a disease called epilepsy, or of a nervous condition called hysteria. In such cases all that you can do, as a rule, is to prevent the patient injuring himself while in a fit. A plug of cloth should be inserted between the teeth to prevent biting the tongue. The clothing should be loosened. In a short time the patient will come out of his own accord. If the trouble is hysteria the patient may not shake, but lie quiet and rigid, with staring eyes. This is a cataleptic fit. Such a patient can often be awakened by pressure upon the supraorbital nerve just above the eye.

Convulsions in children are common with many disorders, as indigestion or worms, or even the swelling and pain caused by a new tooth coming through the gums. Children suffering from convulsions should be immersed at once in a hot bath, and a physician sent for.

Sunstroke. This condition is due to an abnormal elevation of the body temperature as the result of exposure to continuous heat. People who are working upon a hot day and feel dizziness or nausea, with excessive languor, should stop work at once, and seek quiet and cold water, else they may suffer a real sunstroke. Where the patient is very hot the chief object of the treatment of sunstroke is to reduce the temperature. The patient should be stripped and packed in ice, or in cloths dipped in ice water. The ice and water must be applied for an hour or more, with constant rubbing of the body. In some cases the patient is simply exhausted and the body cold instead of hot. In such cases heat has to be applied and hot drinks given.

Croup. This is a very common affection in infancy and childhood. It is an inflammatory condition of the throat,

and may be due to several separate causes. The child's throat appears to be stopped up, and there is great difficulty in breathing. In such cases a physician should be summoned at once. In the meantime hot compresses should be placed about the throat and chest, and a hot mustard footbath given.

Toothache. Insert in the hollow of the tooth a plug of cotton wet with carbolic acid or laudanum or oil of cloves.

Asphyxia. Asphyxia may be due to drowning or smothering, or to coal gas. The treatment is in general the same. If it be a case of *drowning*, turn the person upon his face and allow the water to run from the air passages. Then place him on the back with clothing loosened, and begin artificial respiration. Hold the tongue well forward. To induce artificial respiration, grasp the arms just below the elbows, raise them in a line above the head until they meet, then lower them to the sides, pressing in upon the chest walls, as you come down, to expel the air. Repeat this movement fifteen times a minute, for two hours at least. Respiration has been restored after a much longer interval. At the same time the patient must be kept as warm as possible with blankets and hot-water bottles. As soon as the patient begins to breathe, he can be given aromatic spirits of ammonia in hot water.

Poisoning. A poison is any substance whose nature it is when taken into the body to injure health or destroy life. Many of the substances used about a house, as oxalic acid, ammonia, Paris green, Rough on Rats, the brimstone of matches, and carbolic acid, are violent poisons. It is not an unusual occurrence for a person to take some one of these substances, or some medicine which is poisonous in large amount, by mistake. In such cases prompt measures are necessary.

There are two things to do. One is to give the antidote

of the poison; the other is to get the poison out of the body.

An antidote (Greek *anti*, "against," and *didonai*, "to give") is a substance which will render the poison inactive or offset its effects. Where we know the nature of the poison which has been taken, we must give the antidote at once, and then set to work to rid the body of the poison. Where we do not know the poison, or have not the antidote at hand, we must set to work at once to remove the poison from the stomach.

This may be accomplished by giving the patient a tablespoonful of mustard in a glass of warm water, or a teaspoonful of ipecac. These mixtures will cause almost immediate vomiting and expulsion of the poison. A better method of emptying the stomach is by the introduction of a stomach tube to the organ, and the subsequent siphoning out with warm water.

In cases where the poisoning is due to acids or alkalis, no emetics or tubes should be used.

A list of the common poisons, with their antidotes and the method of treatment in cases where they have been introduced, is here given.

Acids, nitric, sulphuric, hydrochloric, oxalic. Antidote, alkalis. Drink a mixture of soapsuds. Get some magnesia or soda, and mixing a tablespoonful with a glass of water, drink at once. If no magnesia be handy, use lime or chalk, or plaster from the wall. Then drink large amounts of warm water. No emetic.

Alkalis, soda potash, ammonia, lye. Antidote, acids. Drink lemon juice or vinegar in solution. Follow with olive oil or castor or linseed oil, or thick cream. No emetic.

Arsenic. This is present in Paris green, Rough on Rats, Scheele's green, and the medicine known as Fowler's solution. Antidote, hydrated oxide of iron. Give milk and white

of egg, and induce vomiting at once. Then give the hydrated oxide of iron, which you can get at the nearest druggist's. Follow with a solution of salt and water.

Copper, blue vitriol, vertigris. Give white of egg and milk.

Mercury, corrosive sublimate, calomel. Give raw eggs and milk.

Lead, sugar of lead. Induce vomiting. Give Epsom salts.

Matches. The heads of matches contain phosphorus. Induce vomiting. Give soapsuds or magnesia or soda in water. Follow with mucilaginous drinks.

Kerosene. Induce vomiting. Give warm milk.

Opium (*morphine*). This is a common drug. Some of its preparations are laudanum, paregoric, Dover's powder. Diarrhea mixtures and soothing syrups also often contain it. To treat, induce vomiting. Give permanganate of potash, one grain for each grain of morphine taken. Give strong coffee, and keep patient awake by all means.

Carbolic acid. Give milk or white of egg.

Aconite. Induce vomiting. Aromatic spirits of ammonia.

Belladonna. Induce vomiting. Strychnine.

There are several plants which grow about us which are poisonous, such as poisonous mushrooms which may be taken for the edible varieties, wild parsley, and the berry of the mountain ash. When these have been taken, vomiting should be at once induced.

Snake bites are very serious affairs to deal with. Tie a handkerchief above the wound if on a limb. Suck the wound as strongly as possible, wash it thoroughly, and apply some lunar caustic or a red-hot iron to the wound.

Insect bites. Apply ammonia or spirits of camphor, or soda. Cover the wound, if a severe one, lest it become infected with bacteria. Apply cold compresses.

Poison ivy. When a person is poisoned with ivy the poisoned surface should be thoroughly scrubbed with soap

and water and covered with a light gauze dressing which admits the air. Ointments and oils are to be avoided.

There are some substances which are poisons to some people and harmless to others. Thus some people are violently poisoned by certain kinds of shellfish which others eat without disorder.

In the sick room. It is the duty of the strong to minister to the sick. When there is an invalid in the house every member of the household shares in his care with the physician. If we are wise and thoughtful in this ministration it may be the fortune of any one of us to aid materially in making the illness of some sufferer less irksome and his recovery more rapid and sure.

To fit ourselves for this task the first lesson which we must learn is that of cheerfulness and hopefulness. Each time that we enter the sick room we must bring courage and cheering words. Never before the patient or elsewhere, even in the face of the most hopeless conditions, must we give way to despondency or grief. Only those who have stood at many bedsides and watched many hard battles for life can have any idea of the power of courage and hope to win through a serious illness. These have saved more lives than all the medicines in the world, ten times over. They are the shining light which the physician bears always before him, and which we too must bear.

The sick room should be upon the quiet and sunny side of the house, if possible. The bed should be so placed that the patient shall not be exposed to drafts and that he may be reached upon both sides. The temperature of the room should be kept between 60° and 70° F. Fresh air should be coming in constantly through an open window or ventilator.

The furniture of the room should consist of cane chairs or lounges, and a light bed of single size with a hair mat-

tress. A bare floor, with rugs to deaden the noise, is preferable to a carpeted floor.

The odors of the sick room should be removed by ventilation, not by burning pastils or sprinkling scents, which simply cover one odor with another. In all weather the windows should be opened for periods at least, if not all the time.

Care should be observed to have the medicines labeled, so that no mistake can be made in their administration.

If the disease is of an infectious nature all the precautions detailed in the chapter upon infectious diseases must be observed.

CHAPTER XVII

PHYSICAL CULTURE

HOME OR GYMNASIUM EXERCISES—GAMES AND ATHLETICS

IN view of the great advance in the study of physical culture which has come during recent years, and of the undoubted improvement in health and physical development of the race which appears to be coming as the result of the application of the principles of this training in our schools and colleges and association gymnasiums, no book of hygiene would be complete without some account of these methods of systematic physical training.

The object of the various systems of physical culture which are used in some of our schools and all our large colleges is the achievement in each individual of the best possible degree of physical culture which is compatible with an even development on all sides of life. It is not intended primarily to produce trained athletes. That is a special branch of training which may follow this primary culture. But it is the end of all systems to give to each and all a strength of constitution, of frame and muscle and heart and lungs, which will fit them for the endurance of the necessary work of life, and to resist disease.

At the same time that the strength is developed, the pupil gains the poise and grace, the control and coördination of

action, which should go with health and strength, also symmetry of form and richness of the skin and the complexion.

Formerly this development was obtained almost wholly through practice in games and athletic sports, or by the labor which each special individual's occupation entailed. Much of it to-day we obtain from games. There is no better way. But in addition to these games a certain amount of systematic exercise at home or in school gymnasiums is now prescribed. Games were not planned to develop each and every muscle in the body. Even when a variety of sports, as running, rowing, football, is indulged in, certain muscles and parts of the body are likely not to get their full share of development; but in prescribed physical exercise each and every part can be attended to and have some special motion produced for its development. Special exercise should therefore go hand in hand with outdoor games.[1]

For many these physical exercises should precede the games. There are children who are not strong enough to go into active sports without some physical preparation; but after a period of training by the milder methods they become capable of entering them.

A system of physical development may be followed out at home or in some school or gymnasium. A mild but very efficient system may be followed without the use of any apparatus. For progressive development, however, and for advanced work, a certain amount of simple apparatus is necessary.

A very simple apparatus and one sufficient for all purposes is found in what is known as the Whitely Exerciser, or some apparatus made upon a similar plan. This appa-

[1] A striking demonstration of the effect of regular physical exercise practiced under competent directions is found in the results reported by Dr. Beyer, surgeon in charge at Annapolis Naval Academy. From these reports we learn that even so fundamental a matter as growth of the bones — increase in height — is greatly influenced by regular physical training.

ratus consists of an elastic cord with handles at each end, arranged upon a system of pulleys which can be attached to the wall by hooks. One hook is placed at about six feet from the floor, the other about six inches. By changing the attachments of the two pulleys to the upper or lower hooks in turn, the apparatus can be used for exercise of the arms, neck, or legs, and can be adjusted to the standing or sitting positions. There are several sets of apparatus, graded for different strengths. Such an apparatus is desirable, but if necessary one can get along with a set of dumb-bells. Indian clubs, a horizontal bar, or a set of parallel bars entail rather heavy exercise to begin with. They may be used to supplement or follow the primary routine exercises.

The aim of physical culture is the achievement of even development. This entails the selection of sets of exercises to develop each part of the body. In the regulation of exercise the principle of progression is adhered to. The pupil begins with a set of mild exercises and gradually works up to the more severe ones. In each period the exercise is light at first, growing more vigorous after the heart and body are warmed up.

The time of exercise should not be directly after a meal, but may be at any other time.

The parts of the body which must be exercised in turn are the legs, the arms, the neck, the shoulders, the thorax, the waist, the back, the abdomen. For each part a special set of movements is prescribed.

In each set of exercises you will find some which are performed without any apparatus. These represent the mildest forms of exercise. If taken out and grouped together these exercises make a good system for home use. These simpler exercises may be performed with light dumb-bells if desired.

It is best to begin with the exercises for the legs. The pupil takes the proper standing posture, namely, heels together,

toes out at an angle of 90°, knees straight but not stiff, hips back, chest expanded, shoulders even and back, arms hanging at the sides, with palms resting upon the thighs. The body weight should rest upon the balls of the feet, not upon the heels.

Calf muscles:

1. Raise body from floor on toes thirty or forty times.
2. Circle foot from thirty to forty times.
3. Raise foot behind and kick alternately.
4. Stoop and rise alternately, bending at knees (front thigh muscles).

With apparatus:

5. With foot in attachment of apparatus, flex (front leg).
6. With foot attached, flex thigh (back thigh).
7. Stand with side to wall, attach farther foot to exerciser, and abduct leg (outer thigh muscles).
8. In same position, attach to inner leg and adduct (inside thigh muscles).

Arm muscles:

9. Circle hands at wrist.
10. Clasp and extend fingers forcibly.
11. Flex and extend forearms forcibly.
12. Raise arms extended from sides to side of head.
13. Circle arms.
14. Lie face to floor and raise body upon arms extending at elbow.

With apparatus:

15. Flex fingers.
16. Flex forearm.
17. Extend forearm with fingers extended. Back to wall.
18. Stand side to wall. Raise arm to side of head.
19. Stand side to wall. Grasp exerciser with farther hand behind and pull outward.

Nos. 18 and 19 also exercise chest muscles and thorax.

Back of neck and upper back:

20. Bend head forward and back forcibly.
21. Twist neck.
22. Lie face down, and raise face from floor, keeping chest down.

With apparatus:

23. Holding attachment of exerciser behind head, bend head backward.

Shoulders:

24. Extend arms forcibly, throwing them well back.

Nos. 18 and 19, given under arm muscles.

No. 23, given under back of neck and upper back.

25. Face wall, palms together. Circle arms backward to utmost with exerciser.

26. Back to wall, one hand over head, one at side grasping exerciser. Advance together.

27. Back to wall, arms extended. Flex at shoulder.

Chest:

All exercise of arms and shoulder, Nos. 18, 19, 25, 26, 27.

28. Raise arms at full length from sides to head without or with exerciser.

29. Throw arms forcibly back, keeping straight out from shoulder, bring palms together and thus forward and back without, then with, exerciser, both facing and with back to wall.

30. Lie on back on floor. Raise arms above head with exerciser, keeping palms together.

31. Lie on back. Raise arms, keeping straight out from body.

Waist, abdomen, back:

All full-arm movements, Nos. 18, 19, 24, 25, 26, 27, 28, 29, 30, 31.

32. Hands on hips. Bend forward and back to limit.

33. Hands on hips. Bend sidewise to limit.

34. Twist trunk on hips.

35. Sit on floor. Drop backward and resume sitting posture.

36. Lie on back. Raise legs extended over body.

With apparatus:

37. Raise hands from sides, straight out and then to sides of head, keeping straight.

38. Bend forward and back, facing wall.

39. Rowing posture. Bend back forward and back.

40. Lie on back. Raise arms straight over head, bring over face to sides.

In addition to the above exercises, certain breathing exercises with the use of the voice may be practiced under direction. At schools, also, exercises in drill are desirable, since they teach proper methods of standing and walking, and require strict attention in regard to the performance of each separate movement.

Where special defects exist, as round shoulders, high shoulders, a weak waist or abdomen, special exercises are to be taken. These must be prescribed by competent directors.

Before taking up a course of home exercise, one should be examined by some competent person, and obtain directions in regard to the time which he should employ in exercise, the weights which he should use, etc. If a boy begin with too heavy exercise he may injure himself.

At the end of a period of exercise the pupil may take a run or a row, or, after cooling off, a swim.

In regard to the other matters concerning physical culture, the proper food, the observance of regular habits, the general directions upon these subjects which are given in the chapters on hygiene of the various organs are to be followed out.

GAMES AND ATHLETICS

In certain ways the best methods of exercise are found in the out-of-door games of childhood and youth.

These games are entered into as a pleasure, not as a task. There can be no question that more benefit is derived from exercise or labor of any kind in which the interest and pleasure form a constant spur to endeavor, and the mind works in harmony with the muscles.

Almost all of these games entail a certain amount of mental, together with physical, exercise. They teach quick and decisive action, systematic or combined action (team play), in which the individual learns to use his strength in harmony with that of his fellows for the attainment of a common end. They teach discipline, forethought, self-control, the husbanding of one's forces until the proper time for action. They should teach also forbearance, moderation, and even self-sacrifice.

The exercise and training consequent to these games, the

open-air life and regular habits, bring about a splendid general development of the muscular system, the heart, lungs, and vital organs. They give the soundest kind of constitutional strength. In this latter regard they are, if carefully controlled and regulated (not carried to excess), more efficient than gymnasium exercises. Lastly, the participation in these games develops a fine ambition for excellence in physical manhood or womanhood.

To serve their purpose, however, these games must be carefully regulated. There must be no excess. The incentive to excess which competition gives must be offset by the watchful discipline of the supervisor or trainer. All boys who participate should first undergo medical examination.

Those whom physical disabilities make unfit should be developed by methods more susceptible to absolute regulation.

The moral side of the sport should be kept at the highest level. The men should go in to win, but by fair means only. Everything should be in a friendly spirit and aboveboard. All elements of trickiness, of brutality, of hard feeling, should be eliminated.

The glory of physical effort and the pleasure of the sport, not the desire to win, should be the chief incentives to participation and to play.

Finally, the athletic interest should be but a part of the general interest in the development. The ideal of physical culture should go side by side with that of mental and moral culture. One part of each twenty-four hours should be devoted to study, one to athletics, one to social intercourse, one to sleep. The athletics should be taken as a pleasure, not as a task. The desire for the outlet of physical energy pent up during the pursuit of other interests should carry men out unbidden.

The tendency of our modern methods in athletics has

been, in part, away from these best ideals of sport. Especially in our college systems, athletics has become too much an end instead of a means. Some men go to college to become famous as athletes, not to get a full and even development. Study and the other interests of life are neglected. The systems of training entailed by the serious competitions are excessive. Men take special summer training before the college year begins. The work becomes a task rather than a pleasure. The desire to win leads to the employment of unsportsmanlike methods. The intense feeling leads to brutality. The contests become battles rather than friendly competitions.

The system turns out good athletes and well-developed men. It leads to greater excellence from the one point in view, the athletic standpoint. But it injures and, to a certain extent, disables for life a certain number who participate. It inculcates a one-sided ideal, an incorrect sense of proportion. The physical harm which results is not a necessity of the sport. It is due to the improper regulation of it. The blame for this improper method lies partly, as we have already hinted, with public opinion at the colleges. The exactions of competition, and the sacrifices which are required to uphold college honor or attain athletic fame, are excessive. But the blame lies also in great part in the absolutely incorrect and inefficient methods of medical supervision employed in our college athletics.

The subject of the training of athletes is not established upon a scientific basis. It ought to be worked out from a physiological as well as from an empirical standpoint. The medical directors of college athletics, as a rule, are medical men chosen because they have been themselves athletes. They are apt to be men of surgical training whose knowledge of physiology and internal medicine is limited. There should be associated with these men physiologists

who could work out the scientific physiological side of training at the same time that the trainer is working out the empirical side. If this were done we could in the end perhaps gain some accurate knowledge in regard to the proper time and strength (labor) limits of athletic contests, and be able to tell in advance, by examination, what men are capable of standing a certain amount of training and labor in contest without detriment, and what men are not. At present the system is very much one of the survival of the fittest.

Happily this matter of the proper regulation of athletics is now receiving the attention it deserves in some of the colleges, and there is a marked improvement in the methods of training and in the manner of conducting the contests.

GLOSSARY

Special terms are explained in the context, and can be looked up through the Index. Only such terms are explained in the Glossary as have a general meaning or have more than one meaning.

Abdominal cavity, the large cavity of the mammalian body lying below the diaphragm, which contains the liver, stomach, and intestines, spleen, and several other organs. It is continuous below with the pelvic cavity.

Abduction, the removal of anything from a substance or body; the motion of drawing a limb or part away from the midline of the body.

Absorption, the process of taking up nutritive or waste products by the cells or tissues of the body.

Accumulation, the storing up of substances.

Adduction, the motion of drawing a limb or part toward the midline of the body.

Afferent, a term applied to anything traveling or conducting from the periphery (surface) of the body to the interior or to the central organs: afferent impulses, afferent vessels, afferent nerves.

Albumen, or **Albumin,** a special kind of proteid substance contained in food and in the body tissues.

Amœboid motion. The amœba is an animal consisting of a single cell which has the power of changing its form and of moving about in water by protrusions and withdrawals of its substance. Any living cell which performs similar motions is said to have the property of amœboid motion.

Antiseptic (Latin *anti*, "against," and *sepsis*, "poison"), inhibiting the action of a poison. The term is applied specially to substances which inhibit the action of bacteria or other organized ferments.

Apparatus, a device, usually a mechanical one, for the accomplishment of some function or some special aim.

Appendage (Latin *ad*, "to," and *pendeo*, "I hang"), any part attached to a central body or part.

Areolas (Latin dim. of *area*, "a small space"), a term applied to connective tissue so constructed as to contain many spaces.

Articulate, to join in a joint.

Articulation (Latin *articulo*, "I form a joint"), a joint.

Articulatory surfaces, surfaces of bones which enter into the formation of a joint.

Assimilation (Latin *ad*, "to," and *similis*, "like"), the conversion of food substances into living tissue.

Bladder (Saxon *bleddra*, "a bladder"), a bag or sac serving as a receptacle of a secreted fluid.

Canal (Latin *canalis*), a tube or passage through which a substance may flow.

Cardiac, pertaining to the heart.

Catarrh, an inflammatory condition of a membrane, usually attended with an increased secretion of the cells of the membrane.

Chemistry, the study of the force by which matter becomes permanently altered in its properties; that is, the science of the composition of matter and of the changes which it undergoes in this composition.

The chemistry of muscle, for example, is the study of its composition and of the changes which occur in the substances which compose muscle in the processes of metabolism.

Composition. The composition of a substance is its make-up. As ordinarily used the term means the *chemical* make-up. Thus, water is composed of hydrogen and oxygen. The statement, "milk is composed of proteids, carbohydrate fat, and mineral substances," refers also to the *chemical composition*, though not to the ultimate composition, as in the statement in regard to water.

We sometimes use the term in a physical sense. Thus, skin is said to be composed of epithelial tissue and connective tissue.

Compress, a pad or bandage applied directly to an injury to compress it.

Concentrated. A substance, as, for example, the urine, is said to be concentrated when its density is greater than normal.

Congestion (Latin *con*, "together," and *gero*, "I bring"), an abnormal accumulation of blood in a part.

Constipation (Latin *con*, "together," and *stipo*, "I crowd"), retardation or sluggishness of the actions of the intestine, causing accumulation of the fæces in the body.

Constituent, any substance which enters into the composition or structure of a greater whole.

Consumption, a disease of the lungs due to the bacterium known as the tubercle bacillus.

Contraction (Latin *con*, "together," and *traho*, "I draw"), the drawing together of any substance, as protoplasm, or any body, as a muscle.

Decomposition, the breaking up of a substance into its constituents (its chemical constituents).

Degeneration (Latin *degenerare*, "to deteriorate"), a change in an organism or structure which makes it less fit to perform its function or fulfill its usefulness.

Density. The density of a substance is its comparative bulk as compared with an equal weight of some standard substance. Thus, in Experiment 16, page 126, the white of egg is of greater density than the water, a given weight of the former being of less bulk than an equal weight of water.

Detritus, structural material cast off by the tissues or unused portions of food, which make up the excreta of the body.

Dextrin, a carbohydrate substance formed by the digestion of starch.

Diffusion, the flowing apart or separation of substances into other media.

Digestion, the breaking apart of the constituents of a substance; a term usually confined to the breaking up of food in the alimentary canal of the body.

Dissection (Latin *dis*, "apart," and *seco*, "I cut"), the cutting up of a plant or animal for purposes of studying its structure.

Duct (Latin *duco*, "I lead"), a tube which carries substances away from organs, usually from glands.

Efferent, a term applied to anything traveling or conducting from the interior or center of the body to the periphery.

Elastic, possessing the property of stretching, under strain, and returning to its natural condition when the strain is relaxed.

Elimination (Latin *e*, "out of," and *limen*, "threshold"), the expulsion or passing out of substances, especially waste substances.

Emetic (Greek *emeo*, "I vomit"), a medicine used to produce vomiting.

Emulsion (Latin *emulgere*, "to milk"), a fat suspended in a liquid in a very finely divided condition.

Epidemic, the prevalence of a large number of cases of a disease in a community.

Equilibrium, balance. The equilibrium of the nutrition of the body is maintained when the supply of food and the expenditure of tissue balance each other.

Excreta, the refuse which is passed from the body in any way.

Experiment, a trial; the operation of subjecting objects or substances to certain conditions and observing the results, to test some principle or supposition, or to discover some fact.

Fumigation (Latin *fumigare,* "to smoke"), the use of the fumes of a substance to disinfect.

Fuse, to reduce a solid substance to a liquid form.

Gastric (Greek *gaster,* "stomach"), pertaining to the stomach.

Germ (Latin *germen,* "a sprout"), a term applied to organized ferments as first causes of disease.

Germicidal, the power of killing germs (organized ferments).

Glycogen, a carbohydrate substance produced in the liver; also stored up in the muscles.

Gram, the unit of the metric system of weights. It is equivalent to 15.43 grains troy.

Granule, a small particle of material.

Gymnasium (Greek *gumnazo,* "I exercise"), an establishment fitted for conducting muscular exercises.

Hepatic, pertaining to the liver.

Heredity, the tendency of the protoplasm of one individual to possess the inherent characteristics of that of its ancestors.

Homogeneous (Greek *homos,* "the same," and *genos,* "kind"), a substance of uniform composition or appearance.

Hydrogen, a gaseous element which enters into the composition of many substances.

Hydrophobia (Greek *hudor,* "water," and *phobos,* "fear"), a disease occurring in animals, especially dogs, which may be transmitted to man and other animals by the bite of the affected animals.

Idiosyncrasy, a characteristic peculiar to a special individual as distinct from the majority of individuals.

Indestructibility of matter. This term refers to the fact that, in all the changes which matter may undergo, none of the matter is ever lost.

Infectious disease, a disease due to some organism obtaining settlement in the body.

Inflammation (Latin *in,* and *flammo,* "I flame"), a pathological (diseased) condition of a tissue, usually manifesting itself by redness and swelling of the part.

Intelligence, the power of reasoning and of understanding the relations of things.

Lens, a piece of a transparent substance so arranged as to converge or disperse the rays of light.

Liberation, setting free.

Locomotion, the property or act of moving about from place to place by one's own action.

Membrane, a cellular layer of tissue used to cover the surface of some part of the body.

Microbe (Greek *mikros,* "little," and *bios,* "life"), a microscopic organism, as a bacterium.

Mixture, a physical combination of two substances.

Molecule, the smallest quantity into which the mass of any substance can be physically divided, or in which any substance can exist in a free state. Thus, a molecule of sugar is the smallest particle of sugar which can exist. This molecule may be broken into smaller parts called atoms, but these atoms are not sugar, but portions of the elementary substances which are built up together to make the sugar molecule.

Motor (Latin *moveo,* "I move"), a term applied to nerves which conduct impulses which produce motion in a part.

Nostril (Anglo-Saxon *nosu,* "nose," and *thyrl,* "a hole"), one of the two outer openings of the nose.

Nutrition (Latin *nutrio,* "I nourish"), the process of the nourishment of the body and its parts. The term is also used to describe the condition of the body; thus, "the nutrition of the body is good," meaning that the body is well nourished.

Olfactory (Latin *olfacio,* "I smell"), pertaining to the sense of smell.

Optic (Greek *opsis,* "sight"), pertaining to the sense of sight.

Organism, a term applied to any individual entity having the property of a separate life, as an animal body, a plant, or a bacterium.

Ossification, the transformation of any living substance, as, for example, cartilage, to bone.

Paralysis (Greek *paraluo,* "I loosen, disable"), the loss of function—usually applied to a loss of muscular power.

Parasite, an organism which lives upon another plant or animal.

Periphery, the external part or surface.

Process (Latin *procedo,* "I go forth"), a projection of substance; also a method or manner of action by which some end is fulfilled.

Rudimentary. A rudimentary structure is one incomplete in its make-up or function, the vestige of some structure useful in the economy of the bodies of some ancestral race.

Shock. The term is used here to describe any impression or impulse of a disturbing nature received by any sensitive object or structure.

Slant culture, a preparation of some nutrient media for some organism, arranged with an oblique or slanting surface.

Stimulation, increase of vital activity.

Structure. The structure of a body means its building plan. We speak of a muscle as a structure, meaning a thing built up by the physical association of several parts.

Suspension. A substance is said to be in suspension when its physical particles are maintained floating throughout a liquid.

System, a combination of structures and organs for the accomplishment of a definite purpose.

Systemic, belonging to the whole body.

Transformation, change of nature or form.

Translucent, allowing light to pass through.

Utilization, the making use of.

Vessel, a structure which carries materials not a part of itself. In physiology the term is applied to tubes which carry the food and waste substances to and from the tissues, as the blood vessels, the lymph vessels.

Viscera, a term applied to the internal organs.

Vital, endowed with life, or pertaining to living things.

Volition, the power of choice; will.

Water of condensation, the water which collects upon cooling.

INDEX